2.0 IDENTIFICATION AND SCREENING OF TECHNOLOGIES

This section lays the groundwork for developing a range of remedial action alternatives for the Portland Harbor Site. It was developed consistent with EPA *Guidance for Conducting Remedial Investigations and Feasibility Studies under ~~CERLA~~CERCLA* (EPA 1988), EPA *Contaminated Sediment Remediation Guidance for Hazardous Waste Sites* (EPA 2005), and EPA *Principles for Managing Contaminated Sediment Risks at Hazardous Waste Sites* (EPA 2002).

2.1 INTRODUCTION

This section focuses on the development of RAOs that consider the contaminants and media of interest, exposure pathways and preliminary remediation goals; development of general response actions focused on contaminated sediments, and screening remedial technologies and process options based on consideration of site-specific information.

Remedial technologies and process options are evaluated with respect to their effectiveness in achieving remedial action objectives (RAOs) and implementability. Remedial technologies that are retained for further consideration based on site-specific data will be assembled into remedial action alternatives in Section 3.

2.2 REMEDIAL ACTION OBJECTIVES

RAOs consist of media-specific goals for protecting human health and the environment. RAOs provide a general description of what the cleanup is expected to accomplish and help focus alternative development and evaluation.

RAOs specify:

- Contaminants of concern (COCs) for each media of interest;
- Exposure pathways, including exposure routes and receptors; and
- An acceptable contaminant level or range of levels for each exposure route (i.e., preliminary remediation goals [PRGs]).

The following general narrative RAOs have been developed for the Portland Harbor site:

Human Health

- **RAO 1 – Sediments:** Reduce to acceptable levels human health risks from exposure to contaminated sediments resulting from incidental ingestion of and dermal contact with sediments, and comply with identified applicable or relevant and appropriate requirements (ARARs).

- **RAO 2** – **Biota Ingestion**: Reduce to acceptable levels human health risks from indirect exposures to COCs through ingestion of fish and shellfish that occur via bioaccumulation pathways from sediment and/or surface water and comply with identified ARARs.
- **RAO 3** – **Surface Water:** Reduce risks from COCs in surface water at the Site to acceptable exposure levels that are protective of human health risks from ingestion of, inhalation of, and dermal contact with surface water; protect the drinking water beneficial use of the Willamette River at the Site; and comply with identified ARARs.
- **RAO 4** – **Groundwater:** Reduce to acceptable levels human health risks resulting from direct exposure to contaminated groundwater and indirect exposure to contaminated groundwater through fish and shellfish consumption, and comply with identified ARARs.

Ecological

- **RAO 5** – **Sediments:** Reduce to acceptable levels the risks to ecological receptors resulting from the ingestion of and direct contact with contaminated sediments and comply with identified ARARs.
- **RAO 6 – Biota (Prey) Ingestion:** Reduce to acceptable levels risks to ecological receptors from indirect exposures through ingestion of prey to COCs in sediments via bioaccumulation pathways from sediment and/or surface water and comply with identified ARARs.
- **RAO 7** – **Surface Water:** Reduce risks from COCs in surface water at the Site to acceptable exposure levels that are protective of ecological receptors based on the ingestion of and direct contact with surface water and comply with identified ARARs.
- **RAO 8** – **Groundwater:** Reduce to acceptable levels the risks to ecological receptors resulting from the ingestion of and direct contact with contaminated groundwater and indirect exposures through ingestion of prey via bioaccumulation pathways from groundwater, and comply with identified ARARs.

Commented [A1]: This sentence is particularly hard to follow, but I'm assuming it would be problematic to toy with the wording of the RAOs at this point.

In addition to RAOs, management goals were also established for the Portland Harbor Site. These management goals include:

- **Management Goal 1**: Ensure sediment cleanup activities consider, complement, and are compatible with, upland and upstream source control efforts designed to prevent recontamination by COCs in groundwater, stormwater, soil erosion, upstream sources, and overwater activities at the Site and are consistent with the RAOs for the Site; and allow in-water remedies at the Site to proceed in a timely manner.

- **Management Goal 2**: To the maximum extent practicable, minimize the long-term transport of COCs in the Willamette River from the Site to the Columbia River and the Multnomah Channel.

- **Management Goal 3**: Clean up contaminated sediments in a manner that promotes habitat that will support a healthy aquatic ecosystem and the conservation and recovery of threatened and endangered species.

Management goals will be evaluated to ensure a successful remedy. Meeting these goals ~~and~~ will require integration with the implementation of other regulatory mechanisms ~~to implement~~ such as State of Oregon Water Quality and Environmental Cleanup programs. Management Goal 1 requires sediment cleanup activities to be compatible with source control measures being implemented under Oregon Department of Environmental Quality (ODEQ) oversight. Due to the potential overlap between source control measures to address contaminated riverbank erosion and in-water sediment remediation, it is expected that sediment cleanup actions will incorporate riverbank erosion controls as appropriate. As a result, Management Goal 1 will be addressed by~~used to~~ developing general response actions for contaminated riverbanks adjacent to areas of sediment contamination targeted for active remediation (e.g., capping and removal). For riverbank general response actions, the objective is to prevent riverbank erosion that would result in contaminant~~at~~ concentrations that pose a risk to human health or the environment.

The following discussion identifies the COCs, discusses the development of risk-based PRGs for the applicable exposure routes and receptors, and identifies ARARs leading to the development of PRGs for each narrative RAO presented above.

2.2.1 Contaminants of Concern

The BHHRA and BERA evaluated contaminants in sediments, surface water, biota, and groundwater in the Willamette River and the pathways whereby humans, fish, wildlife, and other receptors could be exposed to those contaminants. Contaminants found to pose cancer risks greater than 1 x 10^{-6} or hazard quotients (HQs) greater than 1 were identified as contaminants potentially posing unacceptable risks in the BHHRA. In the BERA, contaminants with HQs greater than or equal to 1 at the end of the risk characterization were identified as contaminants posing potentially unacceptable risks.

The results of the risk characterizations were used to identify COCs for each media of interest. EPA guidance defines COCs as a subset of the contaminants of potential concern[1] (COPCs) that are identified in the RI/FS as needing to be addressed by the response action proposed in the ROD (EPA 1999).~~).~~ Considerations for selecting COCs at Portland Harbor include the magnitude of and confidence in the risk estimate, the

Commented [A2]: Meaning of sentence unclear. Do COPCs need to be addressed in response action or only COCs? Suggest breaking into two sentences to clarify.

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[1] COPCs are defined as those contaminants potentially site-related and whose data are of sufficient quality for use in the quantitative risk assessment.

distribution of contamination and the degree to which contaminants at the site are co-located, contaminant concentrations relative to chemical-specific ARARs, and the frequency at which risk-based thresholds (RBT) or chemical-specific ARARs are exceeded. In some cases, contaminants were grouped based on chemical structure and toxicity. For example, individual PAHs were grouped into total carcinogenic PAHs (cPAHs), total PAHs, total low molecular weight PAHs (LPAHs) and total high molecular weight PAHs (HPAHs).

Commented [A3]: Is a "risk-based threshold" the same as a "risk-based PRG" as discussed in Section 2.2.2? If not, then please define what is meant by "risk-based threshold".

2.2.1.1 Identification of COCs

Contaminants identified as potentially posing unacceptable risk were evaluated based on a range of factors to identify COCs for further evaluation in the FS. **Table 2.2-1** presents the list of chemicals identified in the BHHRA and BERA as potentially posing unacceptable risk and the rational for refining this list into COCs for the FS. The rationale for identifying COCs is described below.

Infrequent and/or Anomalous Detections
While antimony and lead were determined to pose unacceptable risk to humans and ecological receptors, they were eliminated as COCs because the risk estimates were based on a single result in smallmouth bass. These results were considered to be unrepresentative and likely the result of a lead sinker in the gut being incorporated into the chemical analysis.

Commented [A4]: But according to the COC table, lead is still a COC.

Weak Lines of Evidence
A number of contaminants were eliminated as COCs because the estimated risk to ecological receptors was based on a weak line of evidence. These include 4-methylphenol, ammonia, benzyl alcohol, endrin, endrin ketone, heptachlor epoxide, nickel, and phenol.

Commented [A5]: This list doesn't match with the COC table.

Comparison to Background
Silver was eliminated as COCs because reported concentrations did not exceed naturally-occurring background concentrations anywhere at the site.

Co-location with Other Contaminants
Total endosulfan and sulfide were eliminated as COCs due to their infrequent detections, low concentration, and co-location with other contaminants such that the detections of endosulfan and sulfide are wholly contained within the volumes and area (i.e., footprint) of other contaminants that posed greater risk. Specifically, total endosulfan is co-located with total DDx (the sum of 2,4- and 4,4-DDD, DDE and DDT) and dioxins/furans in sediments offshore of the Arkema site, and sulfide is co-located with PAHs in sediments offshore of the Gasco site.

Related Contaminants Addressed by Other Contaminants

- **Individual PAHs:** Although individual carcinogenic PAHs were evaluated in the BHHRA and identified as chemicals potentially posing unacceptable risk, carcinogenic PAHs will be evaluated as total carcinogenic PAHs as benzo(a)pyrene equivalents. The BERA identified total PAHs, total HPAHs, total LPAHs, naphthalene and benzo(a)pyrene as chemicals potentially posing unacceptable risk. Naphthalene and benzo(a)pyrene were not identified individually as COCs because they will be addressed by LPAHs and HPAHs, respectively.

- **Total DDD, DDE and DDT:** While the BHHRA evaluated risk to human health based on the individual sums of 2,4- and 4,4-DDD, -DDE and ~~-~~-DDT~~.~~ ~~These~~,~~.~~ t~~T~~hese contaminants were grouped together for PRG development purposes because 2,4- and 4,4-DDE and -DDD are transformation products of 2,4- and 4,4-DDT, and based on their similar toxicological endpoint. Thus, the individual sums of the chemicals were eliminated as COCs because they are represented by total DDx (the sum of 2,4- and 4,4-DDD, -DDE and -DDT).

- **Beta and delta-hexachlorocylohexane:** Beta and delta-hexachlorocylohexane were eliminated as COCs because they are represented by gamma-hexachlorocylohexane (Lindane) as they are isomers of Lindane and were not found to pose risk in the BHHRA or BERA.

Commented [A6]: Not clear as to meaning of "individual sums". Was it the sum of the individual risks? Should the word "concentrations" be used instead of "sums"?

Commented [A7]: Isn't this the primary reason for eliminating them? At that point, isn't it irrelevant that they are isomers of Lindane?

2.2.1.2 Classification of COCs

Portland Harbor COCs are presented in **Table 2.2-2** and have been grouped by RAO and media. For purposes of the FS, COCs have been classified into three categories: 1) risk-based COCs, 2) media-based COCs, and 3) source-based COCs. The table reflects the category for each COC selected for each RAO.

Risk-Based COCs
Risk-based COCs were identified as posing unacceptable risk to human health or the environment in a specific media based on the results of the baseline risk assessments. Risk-based human health COCs were identified in beach material and in-water sediment (RAO 1 – direct contact), fish tissue (RAO 2 – fish and shellfish consumption), and surface water (RAO 3 – drinking water). Risk-based ecological COCs were identified in sediment (RAO 5 – direct contact and RAO 6- bioaccumulation), surface water (RAO 6 – comparison to bioaccumulation-based aquatic life criteria and RAO 7 – comparison to surface water toxicity reference values [TRVs]), and pore water (RAO 8 – comparison to TZW TRVs). Risk-based COCs are denoted with an "R" in **Table 2.2-2**.

Media-Based COCs
Media-based COCs are contaminants detected in surface water and sediment associated with an exposure pathway found to pose risk to human health and the environment. ~~This is for~~Media-based COCs are applicable to RAOs where the exposure route includes more than one media. For human health RAO 2, the exposure route is consumption of fish which are exposed to contaminated surface water and sediment. Thus, sediment and surface water PRGs are developed to protect all exposure routes to the receptor

(humans). The same process was used for the dietary PRGs for ecological receptors in RAO 6. Media-based COCs are denoted with an "M" in **Table 2.2-2**.

Source-Based COCs
Limited surface water and pore water (TZW) sampling was conducted at Portland Harbor, and samples were not always collected where there was a known contaminated surface water or groundwater source. Consequently, all the COCs that were identified in the baseline risk assessment in other pathways are of concern in the surface water and groundwater source pathways~~.~~ and are deno~~n~~ted with an "S" in Table 2.2.-2. Additionally, five COCs (2,4-D, 2,4,5-TP, PCE, 1,1,1-TCA, and vinyl chloride) that were detected in upland media (storm water and groundwater) at concentrations that indicate the potential for risk to human health or the environment based on exceedance of Safe Drinking Water Act Maximum Contaminant Levels (MCLs) and National or State of Oregon water quality criteria were designated as source-based COCs, and are denoted with an "S" in **Table 2.2-2**. Rather than evaluating source-based COCs directly in the FS, EPA expects that they will be addressed through upland source control measures implemented under ODEQ regulatory authority, remedial design, and long-term monitoring. For the purposes of the FS, an engineered cap will be assumed in any sediment management area (SMA) offshore of where these COCs are present in upland groundwater plumes.

Commented [A8]: This seems a bit out of place. Is this the best place to discuss this?

2.2.2 Risk-Based PRGs

As described above, the BHHRA and BERA results and the NCP [300.430(e)(2)(i)] serve as the basis for defining RAOs in the FS for contaminants in sediment, surface water, biota, and groundwater that pose potentially unacceptable risk via significant exposure pathways. RAOs specify the COCs, receptors, exposure routes and ~~the~~ acceptable contaminant levels (PRGs).~~).~~ PRGs are established, in part, based on the risk-based PRGs developed from the baseline risk assessments for each medium of concern at the Portland Harbor Study Area.

Commented [A9]: Would be helpful to note here or elsewhere at what point PRGs become RGs and, in basic terms, how RGs are selected.

Commented [A10]: Meaning of "in part" not clear. What are the other parts? I think you need something preceding this section that explains the relation of risk-based PRGs, ARARs, background concentrations, and the resulting PRG list.

As described in detail in **Appendix B**, the LWG developed a food web model (FWM) based on protection of upper trophic level receptors. The purpose of the FWM is to ~~assist~~provide a tool to evaluate~~assist with evaluation of~~ risk in the context of the BERA to species ~~from~~ exposed to contaminated sediments~~ in the BERA~~. This model is also being used to establish sediment risk-based PRGs for protection of aquatic life and people that may catch and consume fish and shellfish from the lower Willamette River in the BHHRA. The steady-state model used as the basis for the modeling approach was the model developed by Arnot and Gobas (2004), which was calibrated using data collected from the Study Area during Round 1 and Round 2 field investigations. In addition to the FWM approach, biota-sediment accumulation factors (BSAFs) and biota-sediment accumulation regressions (BSARs) were also used for some contaminants in development of risk-based PRGs. The sections below summarize the development of the risk-based PRGs for the protection of human health and the environment, which are considered during the selection of PRGs.

Commented [A11]: I thought the previous sentence was hard to follow, so I split it in two and tried to clarify. Feel free to improve upon my suggested text though.

Commented [A12]: Wouldn't the establishment of PRGs for the protection of aquatic life be relevant to the BERA, not the BHHRA? The sentence is confusing as written.

Commented [A13]: Needs explanation as to process by which FWM, BSAF, or BSAR was selected for calculation of PRG.

2.2.2.1 Human Health Risk-Based PRGs and Target Levels

The BHHRA presented an analysis of potential for adverse health effects associated with both current and potential future human exposures to hazardous substance releases at Portland Harbor in the absence of any actions to control or mitigate these releases. The BHHRA evaluated exposures and associated risks and hazards to dockside workers; in-water workers; transients; recreational beach users; tribal, recreational, and subsistence fishers; divers; domestic water users; and infants consuming breast milk. The exposure assessment evaluated a reasonable maximum exposure (RME), which is defined as the maximum exposure that is reasonably expected to occur. Estimates of central tendency (CT), which are intended to represent average exposures, were also evaluated. Both cancer risks and non-cancer hazards were evaluated in the BHHRA to identify the contaminants potentially posing unacceptable risks to human health. The BHHRA evaluation of risks and hazards to all potential current and future human exposure pathways, including the most sensitive members of the population, adequately addressed significant human exposures.

Based on the results of the BHHRA, risk-based PRGs for the protection of human health were developed for contaminants for sediment and target levels were developed for contaminants in biota tissue, surface water, and groundwater to meet the objectives associated with RAO 1 (sediment), RAO 2 (ingestion of fish and shellfish), RAO 3 (surface water) and RAO 4 (groundwater). Risk-based PRGs are calculated using three target risk levels, two of which account for the acceptable range of carcinogenic effects (10^{-6} and 10^{-4}) and the third to assess non-cancer hazards at an HQ of 1. The human health risk-based PRG development process for each medium of concern is detailed in **Appendix A Section 1**.

Risk-based PRGs are calculated for five receptors that come in direct contact with beach sediment. The receptors include a dockside worker, transient, recreational beach user, high frequency fisher, and tribal fisher. Similarly, risk-based PRGs are calculated using the same three target risk levels for five receptors that come in direct contact with in-water sediment. These receptors include an in-water worker, high frequency fisher, tribal fisher, diver wearing a wet suit, and diver wearing a dry suit. In addition, risk-based PRGs are calculated to be protective of subsistence fishers who consume fish and shellfish from the Study Area and breast-feeding infants of subsistence fishers. As shown in **Appendix A Section 1**, risk-based PRGs were able to be developed for both RAO 1 beach sediment COCs, all four RAO 1 sediment COCs, and eight of the 13 sediment COCs for RAO 2.

The target tissue levels were calculated using the three target risk levels described above to be protective of subsistence fishers and breast-feeding infants of subsistence fishers. As shown in **Appendix A Section 1**, tissue-based target tissue levels were developed for all 13 COCs for RAO 2.

Commented [A14]: What exactly is meant by "Target Level" and how does it differ from "PRG"?

Commented [A15]: Were the PRGs calculated based on the RME or CT? Please clarify.

Commented [A16]: I see from Appendix A1 that 10^{-6} is the target excess cancer risk. Please clarify the use of the end-points of the range of cancer risk.

Commented [A17]: Why were risk-based PRGs not calculated for some COCs? Is this anticipated to be a substantial data gap?

Commented [A18]: Does this reference to target tissue levels apply only to fish and shellfish, just fish or something else?

Target levels in surface water for RAO 2 are the State of Oregon ambient water quality criteria for protection of human health consumption of organisms (Table 40).~~).~~ Values were available for 12 of the 13 COCs for RAO 2.

Commented [A19]: Add citation to state code.

The only COCs identified through the BHHRA for risk in surface water for RAO 3 is MCPP. The MCLs for drinking water was selected as RBTs for the protection of human health from exposures to surface water and groundwater as a source of drinking water.

2.2.2.2 Ecological Risk-Based PRGs and Target Levels

The BERA presented an analysis of potential for adverse effects associated with both current and potential future ecological exposures to hazardous substance releases at Portland Harbor in the absence of any actions to control or mitigate these releases. The BERA evaluated risks to aquatic plants; benthic macroinvertebrates, bivalves, and decapods; invertivorous, omnivorous, detritivorous, and piscivorous fish; amphibians; invertivorous, omnivorous, and piscivorous birds; and aquatic-dependent mammals under baseline conditions. The BERA evaluated 13 assessment endpoints and 31 measurement endpoints using 55 lines of evidence to identify risks to 24 target ecological receptors.

Based on the BERA, ecological risk-based PRGs were developed for sediment, surface water, and pore water to meet the objectives associated with RAO 5 (direct contact with sediment), RAO 6 (dietary), RAO 7 (surface water), and RAO 8 (pore water). The ecological risk-based PRGs were selected from medium- and contaminant-specific toxicity reference values (TRVs) developed for use in the BERA to be protective of ecological receptors. The ecological risk-based selection process for each medium of concern is detailed in **Appendix A Section 2**.

Commented [A20]: Not clear what's meant by "ecological risk-based selection process". That doesn't seem to be an accurate description of the contents of Appendix A, Section 2.

Sediment TRVs were selected in the BERA to be protective of ecological receptors exposed to contaminated sediments via ingestion and direct contact (RAO 5). Ecological receptors of concern include benthic organisms and several species of fish, birds, and mammals that are representative of distinct feeding guilds, including invertivores, omnivores, piscivores, and detritivores. Risk-based PRGs are also developed from TRVs resulting from the dietary assessment of upper trophic level receptors (RAO 6), including birds and mammals, to protect ecological receptors from indirect exposures through ingestion of prey to COCs in sediments via bioaccumulation pathways using the FWM detailed in **Appendix B**. As shown in **Appendix A Section 2**, risk-based PRGs were able to be developed for all 20 RAO 5 sediment COCs and five of the 12 sediment COCs for RAO 6.

Surface water TRVs were selected in the BERA to be protective of ecological receptors exposed to contaminated surface water via ingestion and direct contact (RAO 7) and for the dietary assessment (RAO 6). Nine COCs in surface water were identified in the BERA as posing risk to aquatic species in RAO 7 and two for RAO 6. Risk-based PRGs had TRVs developed from the BERA for all surface water COCs and for RAO 6 and fifteen RAO 7 surface water COCs.

Transition zone water TRVs identified as RBTs were developed in the BERA to protect ecological receptors from the ingestion of and direct contact with contaminated groundwater and indirect exposures through ingestion of prey via bioaccumulation pathways from groundwater. The TRVs are intended to be protective of benthic organisms and other aquatic life, including aquatic plants, water column invertebrates, fish, and larval amphibians. Risk-based PRGs for pore water were selected for 22 COCs in the BERA.

In addition to the numerical TRVs, the BERA identified acceptable thresholds of risk for benthic macroinvertebrates exposed to contaminated sediments through the completion of sediment toxicity tests conducted on samples collected from~~conducted at~~ 256 stations throughout the Study Area. The sediment toxicity test based RBTs are expressed as the minimum percent survival or the minimum percent biomass reduction relative to survival or biomass in the laboratory negative control sediment response. For a station to fail, the survival or biomass must also be statistically significantly reduced from the laboratory negative control sediment survival or biomass. The BERA classified each individual station as falling within one of four levels of toxicity for each toxicity test: Level 0 (reference areas), Level 1 (low toxicity), Level 2 (moderate toxicity) or Level 3 (severe toxicity). The risk-based PRGs are based on the lower end (i.e., smallest adverse effect) of the Level 2 (moderate toxicity) effect level. These are defined for each test organism and endpoint as follows:

- *Chironomus dilutus* 10-day survival: survival > 84%
- *Chironomus dilutus* 10-day biomass: biomass > 82% of the laboratory negative control biomass
- *Hyalella azteca* 28-day survival: survival > 79%
- *Hyalella azteca* 28-day biomass: biomass > 66% of the laboratory negative control biomass

In addition to having survival or biomass values lower than the percentages above, each individual sample with survival or biomass lower than its respective threshold above must have survival or biomass statistically significantly lower than that of the laboratory negative control sediment response, as determined using either a one-tailed parametric t-test, or a one-tailed non-parametric Mann-Whitney U test, with a statistical significance level of $p < 0.05$. Survival/biomass and statistical significance tests must both fail before an individual sample is considered to have exceeded a risk-based PRG.

2.2.3 ARARs

This section discusses potential ARARs for the Site that have been identified based on the remedial technologies and potential on-site disposal sites contained in one or more of the alternatives to be analyzed in the FS. Final ARAR determinations for the selected remedy will be made in the ROD.

Commented [A21]: This is confusing because ARARs are being used as PRGs where risk-based values are not available as indicated in Table 2.2.14. Should this table in fact refer to "potential ARARs" since "final ARAR determinations for the selected remedy will be made in the ROD"?

Section 121(d) of CERCLA requires remedial actions to generally comply with all applicable or relevant and appropriate federal environmental or promulgated state environmental or facility siting laws, unless such standards are waived. "For the purposes of identification and notification of promulgated state standards, the term promulgated means that the standards are of general applicability and are legally enforceable" (NCP, 40 Code of Federal Regulations [CFR] 300.400[g][4]). CERCLA provides that a remedy that does not attain an ARAR can be selected if the remedy assures protection of human health and the environment and meets one of six waiver criteria.

Commented [A22]: Should there be an additional sentence here explaining that the waiver criteria are explained in 2.2.3.2? Why not include the waiver criteria here?

"Applicable requirements" as defined in 40 CFR 300.5 are,

> *"those cleanup standards, standards of control, and other substantive requirements, criteria, or limitations promulgated under federal environmental or state environmental or facility laws that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstances found at a CERCLA site. Only those state standards that are identified by a state in a timely manner and that are more stringent than federal requirements may be applicable."*

"Relevant and appropriate requirements," also defined in 40 CFR 300.5 are,

> *"those cleanup standards, standards of control, and other substantive requirements, criteria, or limitations promulgated under federal environmental or state environmental or facility siting laws, that, while not 'applicable' to a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA site, address problems or situations sufficiently similar to those encountered at the CERCLA site that their use is well suited to the particular site. Only those state standards that are identified in a timely manner and are more stringent than federal requirements may be relevant and appropriate."*

In addition to ARARs, advisories, criteria, or guidance may be identified as To Be Considered (TBC) for a particular release. As defined in 40 CFR 300.400(g)(3), the TBC category "consists of advisories, criteria, or guidance developed by the U.S. EPA, other federal agencies, or states that may be useful in developing CERCLA remedies." TBCs may be non-promulgated advisories or guidance that are not legally binding and do not have the status of potential ARARs.

Under CERCLA 121(e), federal, state, or local permits need not be obtained for remedial actions which are conducted entirely on-site. "On-site" is defined as the "areal extent of contamination and all suitable areas in very close proximity to the contamination necessary for implementation of the response action" (40 CFR 300.5). Although a permit would not have to be obtained, the substantive (non-administrative) requirements of the permit must be met. Remedial activities performed off-site would require applicable permits.

2.2.3.1 Portland Harbor ARARs

Table 2.2-3 summarizes the ARARs identified to date for use in the FS. In general, there are three categories of ARARs:

- Chemical-specific requirements (**Table 2.2-3a**)
- Location-specific requirements (**Table 2.2-3b**)
- Performance, design, or other action-specific requirements (**Table 2.2-3c**)

These categories are discussed below, and specific ARARs that are important with respect to the FS evaluations are discussed in more detail.

Chemical-Specific ARARs
Chemical-specific ARARs are usually health- or risk-based numerical values or methodologies that, when applied to site-specific conditions, result in the establishment of numerical values. If a contaminant has more than one such requirement that is an ARAR, alternatives should generally comply with the most stringent. The RAOs identify sediment, surface water, and groundwater as media of concern at the Site. Although there are no promulgated federal or Oregon ARARs providing numerical standards for contaminants in sediment, both federal and Oregon standards and criteria are available for surface water and groundwater.

In addition to Oregon WQS, CERCLA requires cleanups to achieve federal National Recommended Water Quality Criteria (NRWQC) if they are relevant and appropriate to the circumstances of the release of hazardous substances at the site [42 USC 9621(d)(2)(A)]. Federal NRWQC are developed to protect ecological receptors and human consumers of fish and shellfish. With respect to application of NRWQC, a comparison of the NRWQC to Oregon's numeric WQS was undertaken. If there was no Oregon numeric WQS and there was a NRWQC, comparisons were made to the NRWQC. If the Oregon WQS had not been updated to reflect the most recent NRWQC, then comparisons were made to the NRWQC. However, if the Oregon numeric WQS was adopted after the most recent NRWQC, but was less stringent due to waterbody-specific reasons, EPA may determine that the NRWQC is not relevant and appropriate as long as the remedy will be protective using the Oregon promulgated standard. Specific Oregon WQS and federal NRWQC and other chemical-specific ARAR numeric values are provided in **Table 2.2-4**. In addition to numeric water quality standards, Oregon narrative water quality criteria are potential ARARs for the cleanup as well that may get translated into numeric standards if needed or appropriate.

Commented [A23]: Does ARAR here need to be qualified as "potential" given statement regarding ARARs and ROD above?

Commented [A24]: I don't understand this. I thought the comparison was between NRWQC and Oregon WQS. What is the comparison if there's no WQS?

The Safe Drinking Water Act (SDWA) limits the amounts of certain contaminants in tap water provided by public water systems. 40 CFR Part 141 establishes the National Drinking Water Standards, or MCLs. MCLs are enforceable standards that establish the highest level of a contaminant that is allowed in drinking water. Because MCLs are drinking water standards, they are considered relevant and appropriate to groundwater and surface water at the Portland Harbor Site. 40 CFR Part 143 establishes the National Secondary Maximum Contaminant Levels or Maximum Contaminant Level Goals (MCLGs). MCLGs are not enforceable guidelines regarding contaminants that may cause cosmetic effects (such as skin or tooth discoloration) or aesthetic effects (such as taste, odor or color) in drinking water. In Oregon, public drinking water systems are subject to the Oregon Drinking Water Quality Act (ORS 448 – Water Systems). While the State of Oregon has exercised primary responsibility for administering the federal SDWA, in practice, the Oregon drinking water standards match the national standards.

Oregon Hazardous Substance Remedial Action Rules [OAR 340-122-0040(2)(a) and (c), 0115 (3),(32) and (51)] set standards for the degree of cleanup required and establish acceptable risk levels for humans and protection of ecological receptors at the individual level for threatened or endangered species and the population level for all others.

OAR 340-122-0040(2)(a-c) requires that hazardous substance remedial actions achieve one of three standards: a) acceptable residual risk levels as defined in OAR 340-122-0115 and as demonstrated by a residual risk assessment, b) numeric cleanup standards developed by ODEQ, or c) background levels in areas where hazardous substances occur naturally. Subsection (b) numeric cleanup standards relevant to the Portland Harbor cleanup have not been developed by ODEQ and, therefore, is not an ARAR for this site.

Oregon Hazardous Substance Remedial Action Rules, OAR 340-122-0115, define the following acceptable risk levels relevant to the Portland Harbor site:[2]

- 1 in 1,000,000 (1 x 10^{-6}) lifetime excess cancer risk for individual carcinogens (e.g., benzo[a]pyrene)
- 1 in 100,000 (1 x 10^{-5}) cumulative lifetime excess cancer risk for multiple carcinogens (e.g., total PCBs)
- A hazard index[3] (HI) of 1.0 for non-carcinogens

[2] OAR 340-122-0115 also provides separate "acceptable risk levels" for probabilistic risk assessments for human health and for individual ecological receptors listed as threatened or endangered, which are not addressed in these bullets.

[3] An HI represents the sum of individual contaminant HQs

- For populations of ecological receptors, a 10 percent or less chance that more than 20 percent of the total local population will be exposed to an exposure point value greater than the ecological benchmark value for each COC and no other observed significant adverse effects on the health or viability of the local population

- For individuals of species listed as threatened or endangered, a toxicity index less than or equal to 1

EPA's target range for managing cancer risk is 1 x 10^{-4} to 1 x 10^{-6}, and the level for noncancer risk is an HQ of 1. While the target risk levels in the Oregon Rules for non-carcinogens and for the protection of ecological receptors are similar to those of the NCP, the Oregon Rules for individual and multiple carcinogens are more stringent than federal law and therefore are an ARAR.

Location-Specific ARARs
Location-specific ARARs are restrictions placed on the concentration of hazardous substances or the conduct of activities solely because they are in specific locations. Some examples of specific locations include floodplains, wetlands, archaeological or cultural resources, historic places, the presence of threatened or endangered species and sensitive ecosystems or habitats. Executive Order 11988, 40 CFR 6.302 on Floodplain Management and the National Flood Insurance Act and Flood Disaster Protection Act, and 42 USC 4001 are significant location-specific ARARs for later FS evaluation and cleanup implementation as relevant and appropriate for assuring that the cleanup does not impact existing flood storage capacity in the Willamette River floodplain. Likewise, the Federal Emergency Management Agency (FEMA) floodplain ARAR requires that any action that encroaches on the floodways of United States waters (such as sediment cleanup) cannot cause an increase in the water surface elevation of the river during a 100-year flood event.

Section 7 of the Endangered Species Act (ESA), 16 USC 1536(a)(2), requires that actions authorized by federal agencies may not jeopardize the continued existence of endangered or threatened species or destroy or adversely modify critical habitat ~~without appropriate mitigation measures~~. It is EPA policy to consult with the National Marine Fisheries Service (NMFS) and the U.S. Fish and Wildlife Service (USFWS) to ensure that actions are not likely to jeopardize the continued existence of any threatened or endangered species or result in destruction or adverse modification of species' critical habitat. Five species of listed salmonids are known to use the Lower Willamette River as a rearing and migration corridor. Moreover, eight listed salmonid species, three additional listed fish species, and one listed mammal species are known to occur in the Lower Columbia River near the confluence with the Willamette River. A preliminary biological assessment will be developed for the proposed remedy to ensure that the proposed cleanup action is not likely to jeopardize the continued existence of any threatened or endangered species present at the site. Further consultation with NMFS

Commented [A25]: Mitigation may ensure against jeopardy or destruction/adverse modification, but as this sentence currently reads it appears you may do one of the above as long as there is appropriate mitigation.

and USFWS will be required prior to implementation of cleanup activities at the Portland Harbor Site.

Action-Specific ARARs
Action-specific ARARs are usually technology- or activity-based requirements or limitations on actions taken with respect to hazardous wastes. These requirements are triggered by the particular remedial activities that are selected to accomplish a remedy. Because there are usually several alternative actions for any site remediation, very different requirements could come into play. These action-specific requirements do not in themselves determine the remedial alternative; they instead indicate how a selected alternative must be achieved. Some federal and state requirements may be both location-specific and action-specific ARARs because they are invoked due to an action occurring on critical habitat or other special location, and they place limits or requirements on how such action is conducted. One such ARAR, important to later FS discussions and cleanup implementation, is briefly described below.

Section 404 of the Clean Water Act (CWA) regulates the discharge of dredged or fill material into navigable waters, with the exception of incidental fallback associated with dredged materials. This ARAR is applicable to cleanup actions in navigable waters of the Site that will discharge dredged material or capping material into the Willamette River or adjacent wetlands. A summary of the Section 404(b)(1) analysis of the proposed remedial alternative has been prepared (cite Appendix). The alternative evaluation process included considerations of the CWA hierarchy to avoid or minimize loss of aquatic habitat or function, but if a loss was deemed unavoidable, then mitigation was included. The final assessment of loss and determination of mitigation will be made during remedial design.

2.2.3.2 ARAR Waivers

If it is found that the most suitable remedial alternative does not meet an ARAR, the NCP provides for waivers of ARARs under certain circumstances. According to 40 CFR 300.430(f)(1)(ii)(C):

"An alternative that does not meet an ARAR under federal environmental or state environmental or facility siting laws may be selected under the following circumstances:

1. *The alternative is an interim measure and will become part of a total remedial action that will attain the applicable or relevant and appropriate federal or state requirement;*

2. *Compliance with the requirement will result in greater risk to human health and the environment than other alternatives;*

3. *Compliance with the requirement is technically impracticable from an engineering perspective;*

4. *The alternative will attain a standard of performance that is equivalent to that required under the otherwise applicable standard, requirement, or limitation through use of another method or approach;*

5. *With respect to a state requirement, the state has not consistently applied, or demonstrated the intention to consistently apply, the promulgated requirement in similar circumstances at other remedial actions within the state; or*

6. *For Fund-financed response actions only, an alternative that attains the ARAR will not provide a balance between the need for protection of human health and the environment at the site and the availability of Fund money to respond to other sites may present a threat to human health and the environment."*

The EPA Office of Solid Waste and Emergency Response (OSWER) Directive 9234.2-25 guidance entitled, *Guidance for Evaluating the Technical Impracticability of Ground-Water Restoration* (EPA 1993), although specific to groundwater, is the primary guidance for technical impracticability (TI) waivers (TI guidance). Although the TI guidance indicates that the TI evaluation may be included in the RI/FS, a TI evaluation is not included in this FS since this FS is not evaluating groundwater remedial actions.

2.2.4 Development of Preliminary Remediation Goals

RAOs provide a general description of what the cleanup is expected to accomplish and help focus FS alternative development and evaluation. RAOs specify the contaminants and media of interest, exposure pathways, and PRGs that permit a range of treatment and containment alternatives to be developed.

PRGs were established for the Portland Harbor Site by comparing the risk-based PRGs developed as part of the baseline risk assessments identified in Section 2.2.2 against the chemical-specific ARARs identified in Section 2.2.3, where available. The most conservative value obtained from this evaluation was used to derive a numeric PRG for each COC for each exposure pathway/media. Because RAOs for the Portland Harbor Site include reductions in tissue concentrations, sediment/water-to-tissue relationships developed based on the results of a site-specific food web model or BSAFs have been used to develop PRGs.

RAO 1 addresses reducing human health risks from incidental ingestion of and dermal contact with contaminated sediments. This includes ~~both~~ exposures to both beach material and sediment. **Table 2.2-5** presents the selected PRGs for the COCs identified for this pathway. All PRGs selected for each COC are based on achieving a target cancer risk level of 10^{-6}. The cumulative cancer risk level for beach exposure is 2×10^{-6} and sediment exposure is 4×10^{-6}.

RAO 2 addresses reducing human health risks from indirect exposures to COCs through ingestion of fish and shellfish that occur via bioaccumulation pathways from sediment

Commented [A26]: I'm confused about the implications of the TI guidance. Because the guidance is specific to groundwater, would it not be applied to this site at a later date? Is the TI waiver (#3 above) still relevant to this site? Is the TI guidance relevant? If you feel this paragraph is necessary, you may want to clarify that a TI waiver could still be granted, despite the lack of groundwater remedial action, if that's the case.

Commented [A27]: Surprised to see a section here with this title. Isn't this what we have been doing in 2.2.2? I see that this section describes how the risk-based PRGs and ARARs are merged to generate the final set of PRGs. I would suggest something earlier on that describes a high-level perspective of the development of PRGs and lays out the organization of the remainder of the discussion of the same. This new high-level discussion might precede section 2.2.2.

Commented [A28]: I find the terminology "risk-based PRG" confusing if it is then superseded by the chemical ARAR or background to become a PRG. But if this is standard terminology, I can accept it.

Commented [A29]: Please be clear as to meaning of tissue. Is this fish/shellfish tissue?

Commented [A30]: Sentence is awkward. Maybe suggest "Because RAOs for the Portland Harbor Site include the goal to reduce chemical concentrations in fish and other wildlife,…"

Commented [A31]: Weren't BSAR values used as well as stated in 2.2.2?

Commented [A32]: Please describe decision process for using food web model, BSAR, or BSAF.

Commented [A33]: Were there ARARs for sediment? If not, then say so.

Commented [A34]: How are these cumulative cancer risks used within the FS? Please add discussion of relevance or consider removing from text.

and/or surface water. Fish tissue and water values are intended to be target levels to be achieved through remediation of sediments and source control actions. **Table 2.2-6** presents the selected PRGs for the COCs identified for this pathway.

- For fish tissue (fillets), no chemical-specific ARAR values were identified through the ARAR process. As a result, all tissue thresholds are based on achieving a target cancer risk level of 10^{-6} or non-cancer hazard quotients equal to one to ensure the cumulative risks are within the acceptable risk levels. The cumulative cancer risk for fish tissue (fillets) is 8 x 10^{-6} and the non-cancer hazard indices is four[4].

- For surface water, thresholds were established based on EPA-approved State of Oregon water quality standards promulgated under the Oregon Water Pollution Control Act (ORS 468B.048) as presented in OAR 340-041-0033, Table 40, Human Health Water Quality Criteria for Toxic Pollutants (organism only)[5], which are established at the 10^{-6} cancer risk levels, except arsenic which is established at the 10^{-5} risk level. Values are not available for mercury, BEHP, or PBDEs. The cumulative risk for surface water is 2 x 10^{-5}.

- For sediment, no chemical-specific ARAR values were identified through the ARAR process. As a result, all sediment PRGs are based on achieving a target cancer risk level of 10^{-6} or non-cancer hazard quotients equal to one to ensure the cumulative risks are within the acceptable risk levels. The cumulative cancer risk for sediment is 9 x 10^{-6} and the non-cancer hazard indices is two.

RAO 3 addresses reducing human health risks from ingestion of, inhalation of, and dermal contact with COCs in surface water and protecting the drinking water beneficial use of the Willamette River. **Table 2.2-7** identifies the PRGs that were selected to address human health risks from surface water/drinking water. PRGs were established at the MCL, where available. If an MCL was not available, the PRG was established at the tap water regional screening level as identified in EPA's "Regional Screening Levels (RSL) for Chemical Contaminants at Superfund Sites" (as of November 2013).

RAO 4 addresses reducing human health risks from direct exposure to contaminated groundwater and indirect exposure to contaminated groundwater through fish and shellfish consumption. **Table 2.2-8** identifies the PRGs that were derived to address human health risks from COCs in groundwater. PRGs were established at the MCL, where available. If an MCL was not available, the PRG was established at the tap water

[4] Hazard indices less than ten (10) are within the uncertainty of the reference dose and are subsequently determined to be acceptable risk.

[5] These values, which are for criteria based on organism + water, are not ARARs as defined in Section 2.2.3~~, which are for criteria based on organism + water~~. Since this RAO is meant to only protect humans from consumption of organisms, the organism only criteria values from the Oregon WQS are being used for this RAO as a threshold value.

Commented [A35]: Index?

Commented [A36]: What is meant by "threshold" in this instance? Is this the same as a PRG?

Commented [A37]: Confusing – Table 2.2-6 says 10^{-4}.

Commented [A38]: Is this a drinking water MCL? Please clarify and cite regulations.

regional screening level as identified in EPA's "Regional Screening Levels (RSL) for Chemical Contaminants at Superfund Sites" (as of November 2013).

RAO 5 addresses reducing risks to ecological receptors resulting from the ingestion of and direct contact with COCs in sediment. **Table 2.2-9** identifies the PRGs that were selected to address direct contact risks to ecological receptors. No sediment-related ARAR chemical values were identified through the ARAR process for Portland Harbor. Risk-based thresholds for sediment were based on achieving a target HQ equal to 1 for each COC. The most conservative risk-based PRG was selected for each COC to ensure protection of all species. In addition, benthic toxicity criteria were established as PRGs for the Portland Harbor Site to guide remedial efforts such that they are protective of the benthic community. These criteria include:

- *Chironomus dilutus* 10-day survival: survival > 84%
- *Chironomus dilutus* 10-day biomass: biomass > 82% of the laboratory negative control biomass
- *Hyalella azteca* 28-day survival: survival > 79%
- *Hyalella azteca* 28-day biomass: biomass > 66% of the laboratory negative control biomass

In addition to having survival or biomass values lower than the above PRG percentages, each individual sample with survival or biomass lower than its respective PRGs must have survival or biomass statistically significantly lower than that of the laboratory negative control sediment response, as determined using either a one-tailed parametric t-test, or a one-tailed non-parametric Mann-Whitney U test (sometimes referred to as the Wilcoxon rank sum test or WRS test~~, either name is fine~~), with a statistical significance level of $p < 0.05$. Survival/biomass and statistical significance tests must both fail before an individual sample is considered to have exceeded a toxicity-based PRG.

RAO 6 addresses reducing risks to ecological receptors from indirect exposures through ingestion of biota (prey) exposed to COCs in sediments via bioaccumulation pathways from sediment and/or surface water. **Table 2.2-10** identifies the PRGs that were selected to address the risk from these pathways. Risk-based thresholds for sediment were based on achieving a target HQ equal to 1 for each COC. The most conservative risk-based PRG was selected for each COC to ensure protection of all species, except for DDE. Surface water PRGs are only present for selected COC from the TRVs developed in the BERA for this pathway.

RAO 7 addresses reducing risk to ecological receptors from ingestion of and direct contact with COCs in surface water. **Table 2.2-11** identifies the PRGs that were selected to address the risk from this pathway. Surface water PRGs were derived by comparing TRVs developed in the BERA against chemical-specific ARAR values.

Commented [A39]: Same comment as above about the meaning of the term "threshold" and relation to "PRG". I believe in this instance this is the same as "risk-based PRG" as discussed in section 2.2.2.

Commented [A40]: Does this mean most conservative over all pathways or all species? Please clarify here.

Commented [A41]: Replace with "conditions must both be met"? Saying a statistical significance test must fail is confusing because I think you mean that statistical significance must be shown (i.e., could be viewed as more of a "passing" the test than failing it).

Commented [A42]: Is this most conservative over all species for which it was calculated? Please clarify.

Commented [A43]: I presume that the lowest value is selected, but it doesn't say so here.

RAO 8 addresses reducing risks to ecological receptors resulting from the ingestion of and direct contact with contaminated groundwater and indirect exposures through ingestion of prey via bioaccumulation pathways from COCs in groundwater. **Table 2.2-12** identifies the PRGs that were selected to address the risk from this pathway. Groundwater (i.e., pore water) PRGs were derived from the BERA TRVs as no chemical-specific ARARs were identified through the ARAR process.

Commented [A44]: This linkage between groundwater and pore water RAOs/PRGs should be made much earlier in the document. I think this is the first time you equate the two.

Table 2.2-13 provides a summary of the Portland Harbor PRGs selected to address the eight Portland Harbor RAOs for each applicable COC. **Table 2.2-14** provides a summary of the basis for the selection of each PRG (i.e., whether the PRG is based on a risk-based threshold, ARAR, or background value).

Commented [A45]: Should this be "PRG" as in section 2.2.2?

Commented [A46]: Background isn't factored into current PRG tables, correct? There's still some discussion of background in this section, but just enough to be confusing. Need to figure out what you want to say about background in Section 2. The concept should not slip in this far into the discussion. Should be introduced earlier (how background will eventually play in) or not at all in this section.

PRGs to be utilized for the evaluation of remedial action alternatives and selecting a response action will be limited to PRGs presented in RAOs 1, 2, 5, and 6. The full range of sediment PRGs will be considered ~~to developdevelop~~in the development of remedial alternatives and ~~assess~~the assessment of remedy effectiveness. Threshold values for fish tissue and surface water will also be used to evaluate remedial action alternatives. Threshold values and PRGs developed for RAOs 3, 4, 7, and 8 will be evaluated through performance designed to measure the success of remedial measures at the Site..

Commented [A47]: Meaning of sentence not clear.

2.3 GENERAL RESPONSE ACTIONS

As described in EPA's general RI/FS guidance (1988), remedial alternatives have the following three components:

- **General Response Actions (GRAs)** – major categories of media-specific cleanup activities such as source control/natural recovery, institutional controls, containment, removal, or treatment that will satisfy the RAOs
- **Remedial Technologies** – types of technologies within each GRA, such as different containment options (e.g., thin-layer capping, engineered caps, active caps)
- **Process Options** – specific variations in the way technologies are implemented such as variations in excavation (e.g., mechanical and hydraulic dredging) and capping specifications (e.g., specific cap armor and chemical isolation layer components)

The focus of this FS is on contaminated sediments. Contaminated sediments throughout the entire Site exceed one or more PRGs established in Section 2.2.4. As a result, sediment GRAs developed in this section apply to the entire Site. However, GRAs for groundwater, surface water and biota are not considered herein, since any contaminated groundwater at the Site will be managed through source control measures, contaminated surface water will be addressed through sediment remediation and source control, and impacted biota will be addressed through sediment remediation and source control efforts. Finally, erosion of riverbank soils may contribute to in-water sediment contamination. Because the control of riverbank soils will be integrated into actions to address contaminated sediments, GRAs have been developed for riverbank soils adjacent to areas targeted for sediment remediation based on Management Goal 1.

Sediment GRAs:

- **No Action** – The No Action GRA is required by the NCP to be carried through the screening process.

- **Institutional Controls** – Institutional controls generally refer to non-engineering measures intended to affect human activities in such a way as to prevent or reduce exposure to CERCLA material often by limiting land or resource use.

- **Monitored Natural Recovery (MNR)** – MNR typically relies upon ongoing, naturally occurring processes to contain, destroy, or reduce the bioavailability or toxicity of contaminants in sediment or soils. As described in Magar et al.~~,~~ (2009), natural processes that are fundamental to the recovery of contaminated sediments (and potentially riverbank soils) include chemical transformation, reduction in contaminant mobility/bioavailability, physical isolation, and dispersion. MNR relies on these processes to reduce potentially unacceptable ecological and human health risks to acceptable levels, while monitoring recovery over time to verify remedy success.

- **Enhanced Monitored Natural Recovery (EMNR)** – Deposition of clean sediment plays a role in the natural recovery of contaminated sediments, and recovery can be enhanced by actively providing a layer of clean sediment to the target area. EMNR refers to the application of a thin layer of clean sediment, typically sand, to a sediment area targeted for remediation. Application thicknesses of approximately 6 inches are common, producing an immediate reduction in surface chemical concentrations. EMNR typically reduces the time to achieve RAOs over what is possible by relying solely on natural sediment deposition where burial is the principal recovery mechanism (EPA 2005).

- **Containment in Place** – As described in EPA (2005), containment in place (e.g., capping) refers to the placement of clean material over contaminated sediments or soils. Caps are generally constructed of granular material, such as suitable fine-grained sediment, sand, or gravel, but can have more complex designs. Caps are designed to reduce potentially unacceptable risk through: 1) physical isolation of the contaminated sediment or soil to reduce exposure due to direct contact and to reduce the ability of burrowing organisms to move contaminants to the surface; 2) stabilization and erosion protection to reduce resuspension or erosion and transport to other sites; and/or 3) chemical isolation of contaminated media to reduce exposure from contaminants transported into the water column. Caps may be designed with different layers (including "active" capping layers that provide treatment) to serve these primary functions, or in some cases a single layer may serve multiple functions.

- **In-Situ Treatment** – In general, in-situ treatment technologies are designed to reduce in-place contaminant toxicity, mobility, or volume. In-situ treatment~~They~~ can include biological, chemical, or stabilization-based technologies, among others, and ~~They~~ are typically based on methods that have been successfully implemented as full-scale ex-~~-~~situ technologies ~~(e.g., biological, stabilization, chemical, etc.).~~

- **Removal** – Removal of sediments and soils can be accomplished either while submerged (dredging sediments) or after water has been diverted or drained (excavation of soils or sediments). Removal or dredging for environmental purposes should be distinguished from maintenance or navigation dredging. For this Site, both environmental dredging and excavation methods necessitate transporting the sediment to another location within the Site or off-Site for treatment and/or disposal.

- **Disposal** – Disposal is the final component of a remediation process train that starts with removal and ends with confinement (disposal) in a facility where potential environmental impacts are monitored, controlled, and limited. This process train can also include ex-~~-~~situ treatment between removal and disposal. Disposal of removed media can either be within an in-water disposal facility specifically engineered for the sediment remediation~~,~~ (i.e., in a confined aquatic disposal [CAD] location or confined disposal facility [CDF]) or within an upland landfill disposal facility such as operating commercial landfills.

- **Ex-Situ Treatment** – Ex-situ treatment is a component of a remediation process train that requires removal before treatment occurs, followed by disposal or beneficial use of the treated materials. Treatment can be defined as any process, manufactured or naturally occurring, which causes the destruction or reduction in toxicity, mobility, or volume of contamination in a given media.

Riverbank GRAs

- **No Action** – The No Action GRA is required by the NCP to be carried through the screening process.

- **Institutional Controls** – Institutional controls refer to engineering controls such as fencing and signage to limit erosion of contaminated material.

- **MNR** – MNR typically relies upon ongoing, naturally occurring processes to contain, destroy, or reduce the bioavailability or toxicity of contaminants in sediment or soils. However, due to wind and vessel generated wave action, accumulation of clean material on riverbanks sufficient to prevent erosion of contaminated material may be limited.

- **EMNR** – Deposition of clean sediment plays a role in the natural recovery of contaminated sediments and nearshore areas during periods of high water. EMNR refers to the application of a thin layer of clean sediment or soil to prevent erosion of riverbank material. Properly sized sand or soil sufficient to prevent erosion of contaminated riverbank soils may have application in low angle slope areas.

- **Containment in Place** – As described in EPA (2005), containment in place (e.g., capping) refers to the placement of clean material over contaminated sediments or soils. Caps are generally constructed of granular material, such as suitable fine-grained sediment, sand, or gravel, but can have more complex designs. Sediment caps can be extended to nearshore riverbank areas to physically isolate contaminated riverbank soils and to physically prevent erosion.

- **In-Situ Treatment** – In general, in-situ treatment technologies are designed to reduce in-place contaminant toxicity, mobility, or volume. In-situ treatment such as solidification/stabilization may be effective preventing erosion of contaminated riverbank soils.

- **Stability Enhancement** – Stability enhancement through regrading, ~~or~~ vegetation plantings, or placement of armor stone or structures can be used to limit the erosion of contaminated riverbank soils. ~~Riverbank~~Maintaining ~~R~~riverbank slopes of greater than 5H:1V and the use of native vegetation ~~is~~ are expected to be effective at preventing erosion of contaminated riverbank soils.

- **Removal** – Removal of contaminated riverbank soils can be accomplished through excavation using standard excavation equipment. Equipment access can be accomplished from shore or with the use of barge mounted equipment. Removal of contaminated riverbank soils can be accomplished in conjunction with nearshore excavation of contaminated sediments using fixed arm excavators. Excavated riverbank soils are not expected to require dewatering but will need to be transported off-site for treatment and/or disposal.

- **Disposal** – Disposal is the final component of a remediation process train that starts with removal and ends with confinement (disposal) in a facility where potential environmental impacts are monitored, controlled, and limited. This process train can also include ex-~~-~~situ treatment between removal and disposal. Disposal of contaminated riverbank soils is more suited to upland disposal than disposal in a ~~confined~~ CDF.

Commented [A48]: Are you talking about maintaining these slopes, creating these slopes, using vegetation where these conditions are not met, or something else?

Commented [A49]: Please add H and V whenever discussing slope to make clear that you are using run over rise instead of rise over run. This comment applies to figures/tables as well.

Commented [A50]: Why is that? Regulatory or technical considerations? May want to mention in passing here.

- **Ex-Situ Treatment** – Ex-situ treatment is a component of a remediation process train that requires removal before treatment occurs, followed by disposal or beneficial use of the treated materials. Treatment can be defined as any process, manufactured or naturally occurring, which causes the destruction or reduction in toxicity, mobility, or volume of contamination in a given media.

2.4 IDENTIFICATION AND SCREENING OF TECHNOLOGY TYPES AND PROCESS OPTIONS

Following EPA's general RI/FS guidance (1988), technologies are typically screened based on simplified evaluations of effectiveness, implementability, and cost. Given the wide array of physical and chemical conditions within the Site and how different technologies could potentially be applied, it is difficult to evaluate the costs of technologies consistently across the Site. ~~Thus~~Thus, although a simplified evaluation of cost was conducted for each technology, no technology was screened out based on cost alone.

Commented [A51]: Or whatever is the best description of your effort re: cost

Screening rules were developed for each technology based on general implementability and effectiveness criteria consistent with EPA's RI/FS guidance (1988):

Commented [A52]: And relative cost?

- **Effectiveness:** The screening level effectiveness criterion evaluated the technology relative to its ability to achieve RAOs. Both short-term and long-term effectiveness were evaluated at a screening level of detail. Short-term effectiveness addressed protection during the construction and implementation periods, while long-term effectiveness evaluated the protectiveness of the technology after construction.

- **Implementability:** The screening level implementability criterion evaluated the technology for technical and administrative feasibility. Technical feasibility refers to the ability to construct, operate, maintain, and monitor the action during and after construction and meet technology-specific regulations during construction. Administrative feasibility refers to the ability to obtain permits for off-Site actions (on-Site actions would be performed under CERCLA authorities) and the availability of specific equipment and technical specialists.

- **Relative Cost:** Cost plays a limited role in the screening process. Both capital and operation and maintenance (O&M) costs are considered. The cost analysis is based on engineering judgment, and each process is evaluated as to whether costs are low, moderate, or high relative to the other options within the same technology type.

It should be noted that the screening of technologies and selection of representative process options was conducted expressly and solely for the purposes of developing detailed remedial action alternatives for this FS. Representative process options are evaluated in the detailed and comparative evaluation of remedial action alternatives.

Retained process options may still be potentially useful under appropriate conditions, subject to more detailed evaluations conducted during remedial design.

The screening of technologies is based on the current Site uses and conditions and/or reasonable likely future conditions and uses for navigation and maintenance dredging ~~issues~~, as currently understood for the Site.

2.4.1 Identification and Screening of Technologies

Table 2.4-1 presents remedial technologies and process options potentially applicable for each GRA at the Site. Descriptions of each process option as well as effectiveness and implementability considerations are presented. Shaded process options are not retained for further consideration due to either effectiveness or implementability concerns. Representative process options are in bolded text.

Representative process options were evaluated to identify the site-specific conditions that may favor one process option over another. Although "No Action" was retained as a process option, it was retained as a regulatory requirement for comparative purposes only and is not discussed further. Remedial technologies were evaluated against the site-specific characteristics to identify technologies considered most effective and implementable. Finally, a list of representative process options was generated that was considered during technology assignment and alternative development. Representative process options will be used for technology assignment and alternative development purposes. In addition, cost estimates developed for the detailed and comparative evaluation of remedial action alternatives will be based on representative process options.

2.4.1.1 Institutional Controls

The term "institutional controls" generally refers to non-engineering measures intended to affect human activities in such a way as to prevent or reduce exposure to CERCLA materials, often by limiting land or resource use (EPA 2005a). As stated in the NCP, EPA expects to use institutional controls to supplement engineering controls as appropriate for short- and long-term management to prevent or limit exposure to hazardous substances, pollutants, or contaminants. The use of institutional controls is not considered a substitute for active remedial measures such as dredging, capping, and in-situ treatment unless such active remedial measures are determined not to be practicable, based on the balancing of trade-offs among alternatives that is conducted during the selection of the remedy. Institutional controls may be used both in the short-term during active remedy implementation to minimize potential for human exposures during construction and in the long-term after active remedy implementation to minimize potential exposures while the system recovers over time to acceptable levels. Institutional controls may also be used to help ensure active remedies remain effective in the long-term, such as government or proprietary controls designed to limit the potential for disturbance to cap areas. EPA's RI/FS guidance for sediment remediation (2005a) notes four broad categories of institutional controls, which can generally be

Commented [A53]: I find this sentence confusing, especially what the word "still" refers to. Could you say that different process options for a given technology may be selected during design, based on more detailed information and a more detailed analysis?

Commented [A54]: I found parts of this section a bit difficult to follow. Dissimilar levels of detail are provided for each GRA, technology, and process option, which is not in itself a problem. However, it results in information being presented in different ways in each section, and I felt like there was a lot of jumping around within each technology section and between the process options. There also doesn't seem to be a consistent section for the discussion of whether a specific technology or process option is determined to be feasible or was screened out. Then some process options were retained that were not even discussed (see my comment re: lagoon dewatering for an example). I don't have an easy fix for this broad issue, but I would suggest (1) ensuring that the outline of each technology discussion is similar, (2) making better use of intro sentences for technology sections and subsections to better guide the reader's attention, and (3) playing around with using bullets, bold text, or call-out boxes to better track the status of the process options within the text itself.

classified as types of institutional control technologies (**Table 2.4-1**). Within those institutional control technologies, process options have been identified for this FS as follows:

- Government Controls
  - Commercial Fishing Bans
  - Waterway Use Restrictions or Regulated Navigation Areas (RNA)
- Proprietary Controls
  - Land use and access restrictions (such as deed restrictions, easements, and covenants, placed in property-related documents or physical barriers, such as fences)
  - Structure Maintenance Agreements
- Enforcement and Permit Tools
  - Permit Processes or Provisions of Administrative Orders or Consent Decrees
- Informational Devices
  - Fish Consumption Advisories

All of these institutional controls can be effective and implementable under a wide range of conditions and generally apply to the entire Site. Consequently, as summarized in **Table 2.4-1**, all the institutional controls outlined above have been retained. Although the effectiveness of institutional controls is limited, particularly for managing ecological risks, they are all considered implementable with proper coordination with state and federal agencies. The relative cost of institutional controls is considered low.

Fish consumption advisories have been retained as a representative process option for the institutional control technology. However, other institutional controls such as regulated navigation areas (RNAs), deed restrictions, and structure maintenance agreements may be subject to enforcement tools under permits, orders, and decrees and may be incorporated into the selected remedy.

2.4.1.2 Monitored Natural Recovery

MNR is defined in EPA's Sediment Remediation Guidance (EPA 2005) as: "ongoing, naturally occurring processes to contain, destroy, or reduce the bioavailability or toxicity of contaminants in sediment." The National Research Council (NRC) defines MNR as a remedy that "relies on un-enhanced natural processes to protect human and environmental receptors from unacceptable exposures to contaminants" (NRC 2000). EPA guidance further recognizes that MNR includes a variety of processes that have the potential to reduce the mass, toxicity, mobility, or concentration of contaminants in the sediment bed. For the purposes of this FS, MNR has the potential to reduce contaminant concentrations through a combination of physical transport (e.g., dispersion, resuspension and transport), chemical and biological degradation, and physical burial processes. Because all three of these MNR processes are expected to occur at the site to varying degrees, all three have been retained as representative process options for MNR.

Sediment trap and suspended solid surface water data collected at the upper end of the Portland Harbor Site suggest that incoming sediment concentrations are far lower than contaminated sediments at the Portland Harbor Site. For example, upstream surface water sampling at RM 16 found that incoming suspended sediment particle PCB concentrations range between 1.5 micrograms per kilogram (µg/kg) and 23.6 µg/kg. This data suggests that MNR may be effective at some locations in Portland Harbor depending on site-specific factors such as initial sediment concentration and sediment deposition rate. Site-specific data will be used to evaluate the effectiveness and implementability of MNR. A summary of the MNR effectiveness and implementability criteria are presented in **Table 2.4-2**. Site data will be evaluated against the MNR effectiveness and implementability criteria and mapped to identify areas where MNR is not expected to be effective.

MNR Evaluation Screening Criteria

Presence of Principal Threat Waste

Under CERCLA, there is an expectation that principal threat waste (PTW) should be treated to the extent practicable. With respect to MNR, the presence of PTW in the form of non-aqueous phase liquid (NAPL) or high concentration source material will unacceptably limit the effectiveness of MNR. As a result, MNR is excluded from consideration as a remedial technology in these areas based on effectiveness.

Sediment Deposition Rate

As described above, the concentration of COCs in suspended sediments entering Portland Harbor is comparable to background concentrations. As a result, deposition of clean material is considered the primary recovery mechanism for MNR in Portland Harbor, and the effectiveness of MNR will be dependent in large part on the rate of deposition. The evaluation of MNR assumes that MNR should be considered a potentially effective technology if the deposition rate is greater than 2.5 cm/year. A deposition rate of 2.5 cm/year was selected because this is the deposition rate that can be reliably detected using the available bathymetric survey data collected between 2003 and 2009. The typical bathymetric survey measurement error range is 0.5 feet (LWG 2012) resulting in an uncertainty range of 1 foot for bed elevation changes between two surveys. The uncertainty range in one direction (i.e., depositional) would be 6 inches, which equates to roughly 1 inch (2.5 cm) per year for period between the May 2003 and January 2009 surveys. Sediment deposition rate based on empirical measurements is presented in **Figure 2.4-1**. MNR is expected to be effective and implementable in areas with deposition rates greater than 2.5 cm/year.

Commented [A55]: If you're referring to two paragraphs up, that's not exactly what it says. It says concentrations in sediments entering the site are lower than those at the site. Do you want to keep to the same sort of statement here?

Commented [A56]: Confusing because Figure 2.4-1 refers to -2.5 as deposition and +2.5 as erosion. This distinction of course becomes important in the EMNR section.

Commented [A57]: Is there a more accurate way to word the last sentence of each of these paragraphs? It's not that MNR is effective and implementable if this condition is met, it's that the criterion supports the selection of MNR if the condition is met.

Surface to Subsurface Sediment Contaminant Concentration Ratios
In general, subsurface sediments in Portland Harbor have higher concentrations of contamination than surface sediments. Areas where surface sediment concentrations are greater than subsurface sediment concentrations suggest an ongoing source of sediment contamination, and thus MNR is not expected to be effective in these areas. Subsurface to surface sediment concentration ratios less than 2 were considered indicative of areas where MNR may not be effective. Surface to subsurface sediment ratios were estimated by interpolating surface and subsurface sediment concentrations for the four primary COCs at the Portland Harbor site (total PCBs, total DDx, total PAHs, and total dioxin/furan TEQ). Surface sediment to subsurface sediment concentration ratios are presented in **Figure 2.4-2** (to be developed). MNR is expected to be effective and implementable in areas with subsurface to surface sediment concentration rations greater than 2.

Commented [A58]: This paragraph jumps between "subsurface to surface" and "surface to subsurface". I suggest you use one convention consistently to avoid confusion.

Commented [A59]: Says 1 in Table 2.4-2

Anthropogenic Effects
Evaluation of MNR should include factors that could prevent accumulated material remaining in place. These lines of evidence include anthropogenic effects such as dredging and propwash activities. Future maintenance dredge areas are considered areas where dredging or propwash induced erosion are likely to prevent the long-term accumulation of newly deposited sediments and thus are areas where MNR is unlikely to be effective. Potential future maintenance dredge areas in Portland Harbor are presented in **Figure 2.4-3**.

Wind and Wake Wave Susceptible Areas
Wind and vessel generated waves have the potential to erode newly deposited sediments. This line of evidence is supported by the presence of coarse-grained sediments along many nearshore areas within Portland Harbor. Due to changes in river stage during a typical year resulting from seasonal variations in river flow, the area subject to wind and vessel generated waves ranges from -0.5 to 14.8 feet Columbia River Datum (CRD). Nearshore areas within this elevation range are considered wind and wake wave susceptible areas and are not considered amenable to MNR due to wave induced erosion potential. Nearshore areas susceptible to wind and vessel generated waves are presented in **Figure 2.4-4**.

2.4.1.3 Enhanced Monitored Natural Recovery

EMNR involves active measures, such as the placement of a thin layer of suitable sand or sediment, to accelerate the natural recovery process. EMNR is often applied in areas where natural recovery may appear to be the most appropriate remedy, yet the rate of sedimentation or other natural processes is insufficient to reduce risks within an acceptable time frame (EPA 2005). The acceleration of natural recovery most often occurs due to burial and/or incorporation and mixing of the clean material into the contaminated surface sediments through bioturbation and physical mixing processes. Other recovery processes can also occur such as binding of contaminants to organic carbon in the clean material, particularly if the material is from a clean sediment source with naturally occurring organic carbon.

The EMNR representative process option is the placement of a thin layer sand cover to accelerate natural recovery through deposition of clean sediment over contaminated sediment. Clean sand or sediment can be placed in a relatively uniform thin layer over a contaminated area or it can be placed in berms or windrows, allowing natural sediment transport processes to distribute the clean material over wider areas. As with MNR, EMNR includes both monitoring and contingency plan components to verify that recovery is occurring as expected, and to respond accordingly. Further screening of EMNR is presented below to identify areas at the site where EMNR is expected to be effective.

EMNR Evaluation Screening Criteria
The EMNR effectiveness evaluation relies on many of the same factors that are considered in the evaluation of MNR. Similar to MNR, the EMNR effectiveness evaluation assumes that deposition of clean material is the primary MNR process that needs to be enhanced. It is assumed that this enhancement will be achieved through the thin-layer placement of 15 to 30 cm of clean sand and that the sand must remain in place in order for EMNR to be effective. As a result, a prerequisite for EMNR is a stable environment that will not erode or remove sediments through current, anthropogenic effects (i.e., dredging for navigation and propwash), or wind or vessel generated waves. Because a stable sediment bed rather than a sediment deposition rate above 2.5 cm/yr is the primary condition for EMNR, the sediment deposition rate criteria was adjusted from 2.5 cm/yr to +/- 2.5 cm/yr. Sediment deposition rates are presented in **Figure 2.4-1**. All other evaluation criteria remain the same as MNR. A summary of the EMNR evaluation criteria ~~are~~ is presented in **Table 2.4-3**.

2.4.1.4 In-Situ Treatment

In-situ treatment technologies generally consist of methods which can be applied with the contaminated materials in place and do not require the removal of the contaminated sediments at the site. In-situ treatment technologies can be categorized into three classes that are potentially applicable based on the treatment methods. These classes include:

1. Biological
2. Chemical
3. Physical

In-situ treatment options for each class are summarized below. Due to the wide variety of contaminants at the site, multiple process options may be utilized at the same location or, where appropriate, a process option targeting a certain set of contaminants may be applied.

Biological In-situ Treatment Technologies
Process options under biological methods include:

Commented [A60]: Not sure what this means. Delete and merge first part of sentence with following sentence?

- Slurry Bioremediation
- Phytoremediation
- Aerobic Biodegradation
- Anaerobic Biodegradation

Slurry Bioremediation
This process option involves the addition of nutrients and other amendments to enhance the bioremediation processes that are occurring within the contaminated sediments. This method is generally applicable only to certain classes of organic compounds and is not applicable for PCBs, dioxins, TBT, or metals. This process requires the installation of sheet piling around the treatment area.

Phytoremediation
Phytoremediation consists of usage of plants to remediate contaminated sediments at the site. Contaminants are rendered harmless either through bioaccumulation, degradation, or chemical changes during assimilation. This technology has only been demonstrated in soil, groundwater, and wetlands and may be applicable in nearshore locations with constructed wetlands. This process would not be viable in areas where there is vessel traffic as the plants would interfere.

Aerobic Biodegradation
This process option uses aerobic microorganisms to degrade organic contaminants in soil, sludge, and solids in-situ. The microorganisms break down contaminants by using them as a food source or cometabolizing them with a food source. Aerobic processes require an oxygen source, and the end products typically are carbon dioxide and water. This process option is not effective in the treatment of inorganic contaminants and has very limited effectiveness in the treatment of highly recalcitrant organic contaminants such as PCBs, dioxins and pesticides. This process may also require injection of oxygen to create aerobic conditions.

Anaerobic Biodegradation
This process option uses anaerobic microorganisms to degrade organic contaminants in soil, sludge, and solids either excavated or in-situ. The microorganisms break down contaminants by using them as a food source or cometabolizing them with a food source. Anaerobic processes are conducted in the absence of oxygen, and the end products can include methane, hydrogen gas, sulfide, elemental sulfur, and dinitrogen gas. Similar to aerobic method, this process option is not effective in the treatment of inorganic contaminants and has very limited effectiveness in the treatment of highly recalcitrant organic contaminants such as PCBs, dioxins, and pesticides.

Chemical In-situ Treatment Technologies
Process options under chemical methods include:

- Chemical Slurry Oxidation

- Chemical Oxidation

Chemical Slurry Oxidation
This process option involves application of chemical oxidants to remediate contaminated sediments. Chemical oxidation typically involves reduction/oxidation (redox) reactions that chemically convert hazardous contaminants to nonhazardous or less toxic compounds that are more stable, less mobile, or inert. This process option can be used to treat most VOCs, SVOCs, pesticides, herbicides and PCBs but would not address inorganic contaminants. This process has not been demonstrated to be effective in full-scale application with contaminated sediments.

Chemical Oxidation
This process option involves the same chemical oxidants used in the chemical slurry oxidation, but the delivery is performed through injection wells. This is generally used for groundwater treatment and is not suitable for sediments. The chemistry involved in this process is also similar to chemical slurry oxidation. This process would not be effective for inorganic contaminants.

Physical In-situ Treatment Technologies
Under this category there are two types of process options; ones in which contaminants are extracted from the sediment and ones in which the contaminants are immobilized within the sediments to prevent contaminant migration.

Extractive process options include:

- Imbiber Beads
- Sediment Flushing

Immobilization process options include:

- Stabilization/Solidification
- Vitrification
- Electrochemical Oxidation
- Carbon Amendments
- Ground Freezing

Imbiber Beads
This process option involves proprietary spherical plastic particles that absorb a very broad cross section of the organic chemical spectrum. These particles are made up of highly absorbent polymer material that enables physical absorption and retention of organic contaminants of up to several times the volume of the spherical particles. This process option is generally used in spill responses and is not effective for inorganic contaminants. The effectiveness of this method in treating contaminated sediment is unknown, although some surface cleanup may be achievable. The contaminants are not

chemically treated and, once used, particles, along with the absorbed contaminants, would have to be disposed of at an appropriate facility.

Sediment Flushing
In-situ flushing is defined as the injection or infiltration of an aqueous solution into a zone of contaminated soil/groundwater, followed by downgradient extraction of groundwater and elutriate (flushing solution mixed with the contaminants) and aboveground treatment and discharge or re-injection. This technology relies on differences in properties such as density, particle size, etc., within the contaminated sediments to extract them. High concentrations of recalcitrant compounds, high percentage of fines and high organic content increases the degree of difficulty in treatment. This process option requires sheet-piling around the treatment area and extensive water quality monitoring outside the piles. This process has been demonstrated on a bench-scale but there are no known pilot or full-scale applications.

Stabilization/Solidification
This process option consists of the addition of reagents that immobilize and/or bind contaminants to the sediment in a solid matrix or chemically stable form. Stabilization refers to those techniques which reduce the hazard potential of a waste by converting the contaminants into their least soluble, mobile or toxic form. Solidification refers to techniques that encapsulate the waste in a monolithic solid of high structural integrity. Contaminant migration is restricted by decreasing the surface area exposed to leaching and/or by isolating the waste within an impervious capsule. Several process options are possible such as addition of mixtures based on Portland cement (cement solidification/ stabilization), sorbent clays such as bentonite (sorbent clay solidification/stabilization), asphalt emulsions, or other commercially available patented mixtures. This process is considered to be technically effective for metals and a variety of organic contaminants, but there would be several implementation issues at the site. There are effectiveness concerns due to the limited ability to perform in-situ mixing and effectively distribute the reagents within the sediments.

Vitrification
This process involves the use of a strong electrical current to heat sediment to temperatures above 2,400ºF to fuse it into a glassy solid. For this method to be effective, the water content in the sediment should be less than 60%. The solid material that results from the in-situ vitrification of the sediments may not be suitable as a habitat. This method involves high energy usage.

Electrochemical Oxidation
This process involves degradation of organic contaminants in-situ by applying an alternating current across electrodes placed in the subsurface to create redox reactions. The effectiveness of this method is limited to mercury and PAHs and requires installation of sheet piling around treatment areas. This technology has not been demonstrated to be effective in applications involving sediments.

Carbon Amendments

This process involves use of carbon (activated carbon or other carbon materials) to reduce bioavailability of organic contaminants, and other amendments to treat a wider range of COCs. The immobilization mechanism involved in this method is adsorption. This method is limited to organic compounds and some metals and works best with lower levels of contaminants but provides a relatively effective and easily implementable way to reduce the mobility of contamination.

In-situ treatment amendments can be placed using a variety of methods including:

- Mechanical mixing of amendments into shallow sediment using injection tines or rotary tilling equipment
- Slurry placement of the amendments onto the sediment surface (e.g., in a clay mixture), potentially including injection or mixing into near-surface sediments
- Mixing amendments with sand, and placing the blended materials using methods similar to the EMNR technology discussed above
- Sequentially placing amendments under a thin sand cover such as broadcast application of amendments in a pelletized form to improve settling characteristics (e.g., SediMite^{TM}; the pellet matrix subsequently degrades, allowing the activated carbon to slowly mix into surface sediments through bioturbation)

Ground Freezing

The ground freezing process converts in-situ porewater to ice through the circulation of a chilled liquid via a system of small-diameter pipes placed in drilled holes. The ice acts to fuse the soil or rock particles together, creating a frozen mass of improved compressive strength and impermeability. Brine is the typical cooling agent, although liquid nitrogen can be used in emergency situations or where the freeze is only required to be maintained for a few days. Long-term effectiveness of this process in the presence of standing water or sediments has not been demonstrated. This method requires installation of an array of pipes within contaminated areas to circulate the cooling fluid.

In-Situ Treatment Evaluation Screening Criteria

As described in **Table 2.4-1**, all in-situ treatment process options except carbon amendments have been eliminated from consideration based on effectiveness and implementability concerns. Numerous field-scale pilot studies have been conducted at other sites to demonstrate the implementability and effectiveness of various carbon amendments to reduce the bioavailability of organic contaminants and certain metals. The use of carbon amendments to treat contaminated sediments has been demonstrated to be effective for a wide range of organic compounds including PCBs, ~~and~~ chlorinated pesticides such as 4,4'-DDT, and PAHs. Application of carbon amendments include direct placement of granulated activated carbon (GAC), powdered activated carbon (PAC), biochar or commercially available materials such as SediMite^{TM} or AquaGate^{TM}.

The effectiveness and implementability of in-situ treatment using carbon amendments is dependent on site-specific conditions. Further screening of in-situ treatment is conducted on Sediment Decision Unit (SDU) basis in Section 2.4.2.4 to identify areas at the site where in-situ treatment is expected to be effective.

A literature review suggests that activated carbon can reduce the bioavailable fraction of PCBs, PAHs, and 4,4'- DDT as measured through porewater concentrations by 90% (Ghosh et al. 2011; Tomaszewski et al. 2008; Zimmerman et al. 2005). In-situ treatment is expected to be similarly effective for other hydrophobic organics such as chlorinated dibenzo dioxins and furans but is expected to be less effective for more soluble organics (e.g., VOCs) or metals. A range of delivery mechanisms are available for GAC (e.g., direct application, and mixing with sand during or prior to placement). The evaluation of in-situ treatment assumes a GAC application rate of 3% to 5% GAC by weight within the biologically active zone. A summary of the in-situ treatment evaluation criteria are presented in **Table 2.4-4**.

Commented [A61]: In this table, eliminate ">" in 40% fines and ">" in 1.0 surface to subsurface ratio. These signs were not used for the MNR or EMNR tables, and it's confusing because >40% supports in-situ treatment, and >1.0 surface to subsurface ratio does not support in-situ treatment (i.e., <1.0 would support in situ treatment). Or include signs for all tables where relevant. Also, in the "Basis" column of this and the other tables, consider wording in terms of which direction would support the technology, not a mix of which would support and which would not support.

The evaluation criteria for in-situ treatment are similar to the EMNR evaluation criteria because the same conditions that would allow a thin layer of suitable sand or sediment to remain in place are the same conditions that would allow in-situ treatment material to remain in place. Further, in-situ treatment can be implemented in conjunction with EMNR to enhance EMNR effectiveness by reducing contaminant bioavailability. However, the effectiveness of in-situ treatment as a stand-alone technology must consider the ability of in-situ treatment to achieve remedial goals. Based on an assumption of 90% effectiveness of activated carbon, it is assumed that contaminant concentrations up to approximately 10 times the lowest sediment PRG can be treated effectively.

As discussed above, the evaluation criteria for in-situ treatment are identical to the EMNR evaluation criteria except for the target treatment concentration criterion. The criteria in common with EMNR include the following:

Commented [A62]: The PTW criterion is in the EMNR table but not the in situ one. Is this intentional? If so, should make mention of this with rationale for not including as in-situ treatment criteria.

- Sediment deposition rate of +/- 2.5 cm/yr, which suggests the sediment bed is stable and amenable to in-situ treatment

- Areas with surface sediment concentrations higher than subsurface sediments suggesting that concentrations are increasing due to an ongoing source of contamination and in-situ treatment is not likely to be effective

- A stable environment that will not erode or remove sediments through current, anthropogenic effects (i.e., dredging for navigation and propwash), or wind or vessel generated waves.

Commented [A63]: I think this would be easier to understand if you phrased each in terms of what would be supportive of in-situ treatment. For instance, deposition rate greater than or equal to +/- 2.5 cm/yr (or maybe that just becomes >= -2.5 (or +2.5, depending on how you're defining erosion vs. deposition – see earlier comment in MNR section) cm/yr, not +/-), subsurface to surface sediment concentration ratio of >1, etc.

Areas that are suitable for EMNR and which meet the target treatment concentration ~~criterioin~~criterion ~~in-situ treatment criteria~~ should be considered candidates for reactive EMNR (i.e., inclusion of reactive material in thin-layer placement). In addition to these criteria that evaluate the effectiveness and implementability of in-situ treatment, there

Commented [A64]: In-situ treatment? Confusing to introduce new term here.

are additional physical conditions at the Portland Harbor Site ~~where~~that indicate the favorability of~~where~~ in-situ treatment ~~may~~relative to other technologies~~may be favorable based on site-specific conditions~~. These include the presence of structures which may hinder cap placement or dredging activities, areas with high groundwater flux that may require the inclusion of in-situ amendments (i.e., GAC) to augment EMNR, and habitat areas where capping or dredging activities may result in a high degree of habitat disruption.

Commented [A65]: I'm not sure if my suggested edits are exactly right, but I tried to clarify the original text.

2.4.1.5 Containment in Place

Containment in place (capping) is a remedial technology for containing contaminants in sediments and preventing or reducing the potential exposure and mobility of those contaminants from the sediment. It involves the placement of a subaqueous covering or cap of suitable material over contaminated sediment that remains in place and is one of the most commonly evaluated and implemented remedial technologies for contaminated sediments (EPA 2005; Palermo et al. 1998). Caps are generally constructed of granular material, such as clean sediment, sand, or gravel. More complex cap designs may include geotextiles, low permeable layers, reactive materials such as activated carbon or organophilic clay, armoring to prevent erosion and habitat layers to encourage recolonization by the benthic community. The sources of capping materials can vary depending on the project and are usually determined in remedial design.

Depending on the contaminants and sediment environment, a cap is designed to reduce potentially unacceptable risk through the following functions (EPA 2005):

- Physical isolation of the contaminated sediment sufficient to reduce exposure due to direct contact and to reduce the ability of burrowing organisms to move contaminants to the surface;
- Stabilization of contaminated sediment and erosion protection of sediment and cap, sufficient to reduce resuspension and transport to other sites; and/or
- Chemical isolation of contaminated sediment sufficient to reduce exposure from dissolved and colloidally bound contaminants transported into the water column.

As presented in **Table 2.4-1**, a range of capping process options has been retained for the Portland Harbor Site. Representative process options include conventional sand caps, armored caps, and reactive caps. The effectiveness and implementability of each representative process option for containment in place is dependent on site-specific conditions. Further screening of capping is conducted on an SDU basis in Section 2.4.2.3 to identify areas at the site where capping is expected to be effective.

Containment in Place Evaluation Screening Criteria

If properly designed and implemented in conjunction with effective source control, capping can be applied across the Portland Harbor Site. The primary limitations of capping are areas of high contaminant flux associated with advective groundwater

Commented [A66]: This sounds like you are saying that with proper design and source control, capping could work throughout the whole site. Then I'm not sure how to interpret the rest of the paragraph – are you saying that the limitations are factors that could be overcome with proper design? This gives the impression that dredging wouldn't be warranted if capping could be made to work anywhere. Since we end up eliminating it as an option in dredging areas, could you say something less sweeping like "…capping can effectively contain contaminated sediments" or "capping can be applied across much of…"

transport, the presence of structures that may limit the ability to place capping materials, water depth requirements (e.g., current or potential future navigation areas), and soft sediment or steep slopes that complicate placement of cap materials. Areas of contamination that are not amenable to MNR, EMNR, or in-situ treatment should be evaluated for capping through a weight-of-evidence evaluation. Capping evaluation criteria to be included in a weight-of-evidence evaluation are presented in **Table 2.4-5**. The factors presented in **Table 2.4-5** help identify areas where capping is expected to be more favorable but will generally not exclude capping from consideration. For example, although water depth may limit the implementability of capping, this limitation can be overcome (although at greater cost) by removing material through dredging prior to cap placement. Generic cap designs that allow cap placement in a wide range of areas can be developed. For example, reactive caps (i.e., cap with an engineered layer incorporated within the cap design to treat material in-situ) can be used in areas with high groundwater and contaminant flux, armored caps can be placed in areas subject to wind and vessel driven waves, and habitat layers can be incorporated into the cap design to allow placement in areas with significant habitat value.

Key elements in the evaluation of capping include the presence of structures that may limit the ability to place capping material and/or increase the costs of capping (**Figure 2.4-5**); the presence of debris and pilings (**Figure 2.4-6**) which may need to be removed prior to cap placement thus increasing capping costs; wave, current and propwash-induced erosion potential (**Figures 2.4-3**, **2.4-4**, **2.4-7**, and **2.4-8**) which may necessitate the use of armoring materials; water depth which may limit the implementability of capping due to navigation depth requirements or the loss of shallow water habitat resulting from cap placement (**Figure 2.4-8**); and habitat considerations which may increase the cost of capping to minimize impacts on benthic habitat. Areas where PTW in the form of NAPL have been identified can generally only be capped if organoclay amendments or other reactive layers are incorporated into the cap design and construction.

Commented [A67]: Figures in this paragraph should be numbered in the order in which they are discussed.

With regard to navigation depth requirements, due to uncertainties regarding future channel depth requirements and required cap thickness, capping was eliminated from further consideration in~~from~~ areas within the federally maintained navigation channel.

With regard to shallow water considerations, it was determined that water depths shallower than 4 feet NAVD88 limit the implementability of capping. This depth estimate was based on a mean lower low water (MLLW) elevation of 1.65 feet CRD (7.03 feet NAVD88) with allowance for construction of a 3-foot cap that maintains submergence at the MLLW (4 feet NAVD88). Dredging prior to cap placement will increase the implementability in shallow water areas by limiting the loss of shallow water habitat and minimizing unacceptable increases in flood rise elevation.

With regard to sediment slopes, where sediment slopes are steep (~~greater~~ steeper than 3:1) capping is generally not considered due to stability issues and has been eliminated from further consideration (**Figure 2.4-9**). Areas where the sediment bed slopes

Commented [A68]: I suggest using “steeper” instead of “greater” because one might logically think that a slope “greater” than 3:1 is 4:1, which is actually shallower, not steeper, using the run over rise convention.

between 5:1 and 3:1 can be capped with special engineering considerations. Information regarding liquefaction potential, slope stability, and sediment shear strength will be required to properly design sediment caps on slopes ~~greater~~ steeper than 5:1. Sediment bed slopes ~~less~~ shallower than 5:1 will not require any special considerations.

2.4.1.6 Removal

Removal of contaminated sediment through dredging ~~or~~ and excavation are the two most common means of removing contaminated sediment from a water body, either while the sediment~~it~~ is submerged (dredging) or after water has been diverted or drained (excavation). Removal of contaminated sediments requires a series of steps:

- Removal – physically removing material from the current location
- Conveyance – moving material to an offloading facility
- Offloading – transporting the material from the water to the land
- Processing – preparing the material for transportation and disposal (e.g., dewatering or treatment)
- Transportation and Disposal – moving the material to its final disposal location

Dredging of submerged sediments may be categorized as either mechanical or hydraulic depending on the basic means of removing the dredged material. Mechanical dredges offer the advantage of removing the sediment at nearly the same solids content and, therefore, volume as the in-situ material. Little additional water is entrained with the sediment as it is removed. Thus, the volumes of contaminated material and process water to be disposed, managed, and/or treated are minimized (EPA 2005). Mechanical dredging is typically accomplished using cable arm dredges with clamshell or enclosed (environmental) buckets or articulated fixed-arm excavators equipped with clamshell-type closable buckets.

Hydraulic dredges remove and transport sediment in the form of a slurry through the inclusion or addition of high volumes of water. Hydraulic dredges may be equipped with rotating blades, augers, or high-pressure water jets to loosen the sediment. The addition of water greatly increases total volume of material to be processed and the volume of water that may require treatment prior to disposal.

In addition to mechanical and hydraulic dredging, specialized and small scale dredging equipment can be used to remove contaminated material below and adjacent to structures such as docks and bulkheads.

Excavation of contaminated sediment generally involves isolating the contaminated sediment from the overlying water body by pumping or diverting water from the area, and managing any continuing inflow followed by sediment excavation using conventional dry land equipment (EPA 2005). At the Portland Harbor Site, isolation of the contaminated sediment is expected to be accomplished through the installation of

Commented [A69]: These steps seem to be for upland disposal only. Disposal options aren't discussed until the next section. Maybe you just need to add "assuming upland disposal" to this sentence?

Commented [A70]: Why is mechanical dredging the representative process option when it sounds like you are planning to drain all the water and then excavate. Need to clarify this point. For instance, does "contaminated sediment" in the next sentence refer only to the most contaminated sediment (e.g., NAPL or PTW)?

sheet pile walls or cofferdams or by accessing the contaminated material during low river stages.

As described in **Table 2.4-1**, mechanical dredging, hydraulic dredging, specialized dredging, and excavation have been retained as removal process options for the Portland Harbor Site. Mechanical dredging has been selected as the representative process option for evaluation in the Portland Harbor FS because it is expected to be the most implementable process option for removing contaminated sediments based on considerations such as treatment of dewatered sediment and the presence of debris.

The effectiveness and implementability of removal using mechanical dredging is dependent on site-specific conditions. Further screening of removal is conducted on an SDU basis in Section 2.4.2.5 to identify areas at the site where removal is expected to be effective.

Dredging Evaluation Screening Criteria
If properly implemented with measures to manage residuals and control releases, dredging can generally be applied across the Portland Harbor Site. The primary limitation of dredging is the presence of debris that can increase release rates by preventing the bucket from closing and structures that can limit the implementability of dredging due to access or stability concerns. Dredging evaluation criteria to be included in a weight-of-evidence evaluation are presented in **Table 2.4-6**. The factors presented in **Table 2.4-6** will generally not exclude dredging from consideration but may limit the implementability and cost effectiveness of dredging. Through proper management, many of the factors that limit the short-term effectiveness and implementation of dredging can be overcome. Dredging should be considered for all areas that are not suitable for MNR, EMNR or in-situ treatment.

Key elements in the evaluation of dredging include the presence of PTW, which may increase the potential for short-term releases and necessitate the use of more robust water quality controls (e.g., sheet pile containment); the presence of structures (**Figure 2.4-5**) and rock, cobbles or bedrock within the dredge prism (**Figure 2.4-9**) that may limit the ability to dredge, require the use of specialized dredging equipment or the removal of structures or obstructions prior to dredging; the presence of debris and pilings (**Figure 2.4-6**) which may need to be removed prior to dredging activities or have the potential to increase releases during dredging; high current areas which may limit the effectiveness of silt curtain water quality controls (**Figure 2.4-7**); water depth and bottom slope which may require special considerations during implementation of dredging activities (**Figures 2.4-8** and **2.4-9**); and habitat considerations which may require increased mitigation costs due to disruption of benthic and/or shallow water habitat. In the navigation channel and potential future maintenance dredge areas (**Figure 2.4-3**), dredging is the most implementable technology, as the other technology options require material to be left in place.

2.4.1.7 Disposal

Disposal is defined as the placement of dredged or excavated material and process wastes into a temporary or permanent structure, site, or facility (EPA 2005). On-site disposal involves placement of materials at an appropriate on-site location where the contaminated material can be properly contained. It is necessary that this containment be maintained and monitored over the long-term to ensure effectiveness. Off-site disposal options are generally limited to disposal in a commercial landfill. In some cases, contaminated sediment may be treated prior to disposal.

Disposal technologies considered in the Portland Harbor FS include:

- Off-site Disposal
  - Commercial Landfill

- On-site Disposal
  - Confined Aquatic Disposal Facility (CAD)
  - Nearshore Confined Disposal Facility (CDF)
  - Upland Disposal Facility

Commercial landfills considered for off-site disposal included the Hillsboro Landfill in Hillsboro, Oregon; North Wasco County Regional Landfill in The Dalles, Oregon; Roosevelt Regional Landfill in Roosevelt, Washington; Columbia Ridge Landfill in Arlington, Oregon; and the Subtitle C landfill at Chemical Waste Management of the Northwest Landfill in Arlington, Oregon.

On-site disposal options considered in the FS include a generic upland disposal facility to be constructed at the site; five CAD facilities to be constructed within the Willamette River at RM 4.5 and RM 9, within the upper end of Swan Island Lagoon, within the Columbia River at RM 102.5 and within Ross Island Lagoon; and three nearshore CDFs to be constructed at Terminal 4, Slip 1; Swan Island Lagoon; and Arkema.

2.4.1.7.1 On-Site Disposal

In-Water Confined Aquatic Disposal (CAD) Facilities
A CAD involves placement of contaminated materials under water in a naturally occurring depression, within an excavated cell or in an area segregated from surrounding surface waters with a submerged berm or other containment structure. The confining cover of a CAD facility would be completed below water as shown conceptually in **Figure 2.4-10**. Five in-water locations were potentially identified (**Figure 2.4-11)** as disposal options under this technology. They include:

Commented [A71]: Please add a notation on the figure that only T4 is carried forward in the FS.

1. Willamette River Mile (RM) 4/5 CAD
2. Willamette RM 9 CAD
3. Columbia RM 102 CAD
4. Ross Island CAD

5. Swan Island Lagoon CAD

Of the five potential CAD options listed above, three (Willamette RM 4/5, Willamette RM 9, and Columbia RM 102) are located at least partially within a navigation channel and two (Swan Island Lagoon and Ross Island) are located in off-channel areas.

Nearshore Confined Disposal Facilities (CDFs)
Nearshore CDFs consist of a disposal cell constructed by creating a berm or barrier between the water and the shoreline and filling the cell with contaminated material up to the water line, followed by a surface cover that is above the water line (shown conceptually in **Figure 2.4-10**. CDFs are similar to CADs, except the vertical berm or barrier is the primary system that minimizes transport of sediment contaminants back into the surrounding water because the cover surface is above the waterline. Three nearshore CDF locations (**Figure 2.4-11)** were potentially identified. These CDFs are described below:

1. Swan Island Lagoon CDF
2. Terminal 4, Slip 1 CDF
3. Arkema CDF

Mechanical excavation with barge conveyance was identified as the representative process option for the removal general response action during the remedial technology evaluation and screening step. Transport of contaminated sediments to on-site disposal locations focused on the use of barges to transport material from the dredge locations to the on-site disposal facility. The mechanically dredged sediments were considered to be hydraulically transported from the barge to the on-site disposal facility.

Commented [A72]: Says mechanical dredging above; see my comment above on this point.

Generic Upland On-Site Upland Disposal Facilities
A generic upland disposal site in close proximity to Portland Harbor was carried into the screening process. However, no sites were identified that have appropriate location and~~,~~ physical characteristics, and for which the property owners expressed an interest in constructing or allowing the construction of a disposal site. As a result, the generic off-site upland disposal site was eliminated from further evaluation during the preliminary screening step.

Effectiveness
If properly designed, all on-site disposal options (CADs and CDFs) are considered effective over the long-term, although they will require ongoing operation, maintenance and monitoring to remain effective. Short-term effectiveness is expected to be lower for CADs than for CDFs due to a higher potential for releases during open water placement in a CAD and the ability to control releases during CDF filling through berm construction. Short-term impacts on workers and on the community are expected to be similar for either option. Long-term effectiveness may be compromised for on-site disposal options in the event of a catastrophic failure (such as seismic failure) or releases to the surrounding water body due to contaminant migration associated with

groundwater flow. However, short-term effectiveness of on-site disposal is expected to be slightly higher than off-site disposal due to the decreased handling of the material and decreases in the potential for accidents due to the shorter transport distances with on-site disposal.

CAD Implementability

Technical implementability associated with the availability of services is expected to be similar for all on-site disposal options. The screening evaluation determined that all five CAD sites could be effectively designed but that all have multiple implementability challenges due to technical issues. These issues include disposal capacity, construction and filling (especially for sites within navigation channels), and long-term maintenance. CADs within the navigation channel have the lowest implementability of all the disposal options due to potential impacts on navigation during filling. In addition, the Ross Island Lagoon option was considered less implementable because it is located adjacent to natural habitat and recreational areas. The Swan Island CAD was eliminated as a representative disposal option because it is not expected to be implementable due to the administrative need to receive approval from and coordinate with the surrounding land owners. As a result, CADs have not been retained as representative process options for further evaluation in this FS.

Commented [A73]: What does this mean? Warrants clarification

CDF Implementability

While all three CDFs are considered implementable, the Terminal 4 CDF is considered most implementable because the surrounding property is owned by a single party, and impacts on floodrise are expected to be less than for a CDF constructed offshore of Arkema due to ~~its~~ the Terminal 4 CDF's off-channel location. In addition, a 60% design document for the Terminal 4 CDF has already been prepared suggesting that construction of a CDF at the Terminal 4 location is more viable than other locations. Other CDFs also involve administrative implementability issues - the Swan Island CDF would require approval of the surrounding property owners adjoining the proposed CDF, while the Arkema CDF would only be available for contaminated material generated at the Arkema site. It should be noted that the Swan Island CDF disposal capacity (1.36 million cubic yards) is substantially higher than the Terminal 4 CDF disposal capacity (670,000 cubic yards).

Commented [A74]: Does the mere existence of the design document suggest this, or was an analysis conducted that suggests that T4 is the best location?

Relative Costs

Relative costs are moderate to high for CADs and high to very high for CDFs and vary depending on the location of the facility. Factors such as capacity of the facility, presence of the location within a navigation channel, distance of transport, and administrative concerns (such as approval from adjacent property owners) may affect overall disposal costs for either a CAD or~~f~~ CDF.

Conclusion

Based on screening and evaluation of effectiveness, implementability and relative costs of several on-site disposal process options, the Terminal 4 CDF is retained as a representative process option for further evaluation under the development of remedial alternatives.

2.4.1.7.2 Off-Site Disposal

This technology is similar to on-site disposal, except that the contaminated materials are transported to an appropriate off-site location or facility for long-term disposal. Contaminated sediments at the site, including the NAPL offshore of the Gasco and Arkema sites, may be disposed of at an appropriate facility as long as the disposal requirements for the facility are met.

Four regional, commercial, licensed landfills permitted under Resource Conservation and Recovery Act (RCRA) Subtitle D and Oregon Solid Waste requirements (OAR chapter 340, divisions 93 through 97) for disposal of non-hazardous waste and one RCRA Subtitle C permitted landfill from nearby locations were considered in the screening process. These facilities were considered based on their proximity to the site, waste acceptance criteria, and transportation methods available. Their locations are shown in **Figure 2.4-12**. These facilities include:

1. Hillsboro Landfill (Hillsboro, Oregon)
2. North Wasco County Regional Landfill (The Dalles, Oregon)
3. Columbia Ridge Landfill (Arlington, Oregon)
4. Roosevelt Regional Landfill (Roosevelt, Washington)
5. Subtitle C landfill at Chemical Waste Management of the Northwest Landfill (Arlington, Oregon)

Although four commercial Subtitle D landfills were considered, only the Columbia Ridge and Roosevelt Regional landfills were retained for disposal of large volumes of contaminated sediment by rail or truck. Due to the similarity between these two regional landfills, the Columbia Ridge landfill was retained as a representative commercial upland landfill disposal option for non-hazardous waste that met the requirements for Subtitle D landfills. Chemical Waste Management of the Northwest landfill was retained for materials that did not meet acceptance criteria of the Subtitle D landfills.

Commented [A75]: Confusing as written because begs question of why Columbia Ridge was selected. You provide justification several paragraphs down. Can you move that language up here or at least reference the text to follow?

Mechanical excavation with barge conveyance and mechanical offloading were considered to be the representative process options for the removal general response action during the remedial technology evaluation and screening step. Transport of contaminated sediments to upland disposal sites focused on the use of barges to transport material from the dredge locations to a transload facility to be constructed on a centrally located 20 acre site within Portland Harbor. Under this assumption, material is offloaded from barges to the transload facility, mixed with a minimal amount of diatomaceous earth to absorb excess water and improve material handling, stockpiled, and transferred to railcars for transport to upland disposal sites.

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Effectiveness
All off-site disposal options that meet the facility's disposal requirements are considered to be highly effective. Long-term effectiveness is expected to be highest for off-site disposal compared to on-site disposal because the potential for releases to the surrounding water body due to contaminant migration associated with groundwater flow or catastrophic failure due to seismic failure are eliminated. However, short-term effectiveness of off-site disposal is expected to be slightly lower than on-site disposal due the increased handling of the material and increases in the potential for accidents due to the longer transport distances required by off-site disposal.

Implementability
Off-site disposal in a commercial landfill is considered more implementable than on-site disposal because the infrastructure for disposal and management of the material currently exists for off-site disposal. Other considerations include the volume capacity of the off-site disposal facilities to handle the quantity of contaminated sediment generated at the site during dredging (including the material added during dewatering). Based on the volume capacities of the representative Subtitle D landfill (Columbia Ridge landfill) and Subtitle C landfill (Chemical Waste Management of the Northwest landfill) and the expected volume of contaminated materials that would be generated at the site, off-site disposal ~~option~~ is easily implementable.

Relative Cost
Relative costs are moderate for disposal at Subtitle D landfills and high for disposal at Subtitle C facilities. The actual cost would depend on the volume of contaminated materials that do not meet the Subtitle D landfill requirements.

Conclusion
Based on screening and evaluation of effectiveness, implementability and relative costs of several off-site disposal process options, all off-site commercial landfill disposal options were retained as process options. However, disposal at either the Columbia Ridge Landfill or the Roosevelt Regional Landfill are considered the most feasible disposal options for contaminated sediment generated at the Portland Harbor site. The Chemical Waste Management Subtitle C landfill is retained for disposal of material that does not meet Subtitle D disposal requirements. In the case of Subtitle D landfills, the Columbia Ridge and Roosevelt landfills offer essentially the same effectiveness and implementability. Due to the similarity of effectiveness, implementability, and transport distance and method (which impacts costs) associated with these two options, only one needs to be incorporated into remedial alternatives as a representative example for the detailed evaluation. Therefore, the Columbia Ridge Landfill was retained as the representative process option for identified off-Site landfill disposal.

2.4.1.8 Ex-Situ Treatment

The majority of sediment removed from Superfund sites is not treated prior to disposal because sediment sites often have widespread low-level contamination (EPA 2005). However, in some instances, treatment may be required to meet on-site or off-site disposal requirements, to minimize the volume of material requiring disposal, or to meet NCP expectations regarding the treatment of PTW, which the NCP acknowledges is more difficult to treat. However, pretreatment, such as particle size separation to distinguish between hazardous and non-hazardous waste disposal options, is common. Although the NCP provides a preference for treatment for "principal threat waste," treatment has not been frequently selected for sediment. High cost, uncertain effectiveness, and/or (for on-site operations) community preferences are other factors that lead to treatment being selected infrequently at sediment sites. However, treatment of sediment could be the best option in some circumstances, and innovations in ex-situ or in-situ treatment technologies may make treatment a more viable cost-effective option in the future.

The treatment of contaminated sediment is not usually a single process, but often involves a combination of processes or a treatment train to address various contaminant problems, including pretreatment, operational treatment, and/or effluent treatment/residual handling. Some form of pretreatment and effluent treatment/residual handling are necessary at almost all sediment removal projects. Sediment treatment processes of a wide variety of types have been applied in pilot-scale demonstrations, and some have been applied full-scale. However, the relatively high cost of most treatment alternatives, especially those involving thermal and chemical destruction techniques, can be a major constraint on their use (NRC 1997). The base of experience for treatment of contaminated sediment is still limited. Each component of a potential treatment train is discussed in the next section.

Ex-situ treatment is used in combination with on-site or off-site disposal. Because treatment is expected to be utilized to a limited degree at the Portland Harbor Site, no treatability or pilot studies have been conducted in support of the Portland Harbor FS. Treatment technologies considered in the FS have been divided into four broad treatment technology categories for the purpose of screening remedial technologies and process options:

- Physical Treatment
- Chemical Treatment
- Biological Treatment
- Thermal Treatment

Some of the process options may involve more than one of the above categories. For instance, stabilization/solidification and sediment washing involve both physical and chemical mechanisms as part of the treatment. In such cases, for convenience, they would be categorized under the mechanism that is deemed as ~~the most~~ predominant.

Physical Treatment Technologies
Physical treatment technologies treat contaminated sediments by reducing contaminant mobility or the volume of material that requires off-site disposal. Physical treatment

also includes sediment dewatering through passive, mechanical, or reagent dewatering processes.

The process options under physical treatment technologies screened as part of this FS include:

- Particle Separation
- Stabilization/Solidification
- Sediment Washing
- Dewatering

Physical Technologies Description Summary

Particle Separation

Particle separation technology consists of several process options that do not immobilize or destroy contaminants; however, they reduce waste volumes that would otherwise require subsequent landfill disposal. Generally, separation of sandier particles with less contamination is performed as part of the process. However, this technology is not very suitable for sediments with small/uniform grain size and/or high organic content.

Stabilization/Solidification

Stabilization/solidification involves the addition of a reagent or a mixture of reagents to the contaminated sediment that may chemically bind the contaminated materials and/or decrease the hydraulic conductivity of the contaminated material thus limiting the overall migration of contamination. Stabilization refers to those techniques which reduce the hazard potential of a waste by converting the contaminants into their least soluble, mobile, or toxic form. Solidification refers to techniques that encapsulate the waste in a monolithic solid of high structural integrity. Contaminant migration is restricted by decreasing the surface area exposed to leaching and/or by isolating the waste within an impervious capsule. Several process options are possible such as addition of mixtures based on Portland cement (cement solidification/stabilization), sorbent clays such as bentonite (sorbent clay solidification/stabilization), asphalt emulsions or other commercially available patented mixtures. It should be noted that this technology would increase the disposal volumes, and this should be taken into consideration during remedial design.

Sediment Washing

This technology relies on differences in properties such as density, particle size, etc., within the contaminated sediments to separate them into clean waste streams and more concentrated streams, thus reducing the volume that needs to be disposed of. A few patented processes are commercially available, the most popular being the BioGenesis^{SM} Advanced Sediment Washing system. High concentrations of recalcitrant compounds, high percentage of fines, and high organic content increases the degree of difficulty in treatment.

Commented [A76]: “cleaner?”

Dewatering
As mentioned previously, dewatering technology is an ancillary technology which, by itself, would not be effective in addressing contamination. It is combined with other primary removal, treatment, and /or disposal technologies to achieve the RAOs. Several process options such as passive in-barge dewatering, lagoon dewatering, geotextile tube dewatering, mechanical dewatering using filter presses, and dewatering using chemically absorbent reagents are available under this technology. Because sediment dewatering is considered an ancillary technology, sediment dewatering is evaluated separately below.

Chemical Treatment Technologies
Chemical treatment technologies actively treat contaminated sediment through chemical processes to degrade, destroy, or reduce the volume of contaminated material. Overall, chemical treatment of contaminated sediments is generally not feasible based on effectiveness, implementability, and cost.

Commented [A77]: Seems kind of out of place relative to other sections. Should this conclusion be saved for screening evaluation section?

The process options under chemical treatment technologies screened as part of this FS include:

- Acid Extraction
- Solvent Extraction
- Chemical Oxidation/Reduction
- Solar Detoxification
- Dehalogenation
- Radiolytic Dechlorination

Acid Extraction
This technology uses acids to extract contaminants from the dredged sediments. Acid extraction is suitable for treating sediment contaminated with metals but is not considered applicable to PCBs, dioxins, SVOCs, PAHs or pesticides.

Commented [A78]: Is some of what you say about solvent extraction below also relevant to acid extraction? E.g., techniques similar to laboratory extraction, doesn't treat contaminants but simply separates them, extracted material still contains contamination? If so, you may want to point that out here. If not, you may want to call out the differences.

Solvent Extraction
This technology uses solvents to extract contaminants from the dredged sediments. The contaminants are not treated but separated from the sediment material due to their preference for the solvent phase. This technology is applicable to only organics and involves techniques similar to how the chemicals are extracted in the laboratory using solvents prior to analysis. This process does not chemically treat the contaminants but simply separates them from the material. The extracted material still contains contamination and would have to be addressed through a viable remedial technology. This process option mainly targets PCBs; hence, additional measures would be required to address metals.

Chemical Oxidation/Reduction

This technology chemically oxidizes or reduces contaminants in excavated waste materials to less toxic compounds that are more stable, less mobile, and/or inert. Commonly used reducing/oxidizing agents are ozone, hydrogen peroxide, hypochlorites, chlorine, and chlorine dioxide. This technology is generally applicable to metals and less effective for SVOCs, petroleum hydrocarbons, and pesticides.

Solar Detoxification

This technology relies on sunlight to treat the contaminated sediments. Under this process option, contaminated sediments are spread on large staging areas thus exposing them to sunlight. Exposure to concentrated sunlight treats contaminants such as VOCs, SVOCs, PAHs and pesticides. This method does not treat PCBs or dioxins.

Commented [A79]: Or metals

Dehalogenation

This technology involves chemical treatment of chlorinated contaminants into less toxic end products through dehalogenation. This technology is limited to chlorinated organics such as PCBs and dioxins.

Radiolytic Dechlorination

This technology involves radiolytic (electron beam) and photolytic (ultraviolet [UV]) dechlorination of PCBs.

Biological Treatment Technologies

Biological treatment technologies rely on biological processes to degrade contaminants into less toxic compounds. Demonstrations have shown that properly designed ex-situ bioremediation systems can treat petroleum hydrocarbons, solvents, non-persistent pesticides, and wood preservatives (e.g., PAHs) on relatively small scales and in ideal conditions, and reductions in contaminant concentrations up to 85 to 90 percent could be achieved (EPA 2004). While bioremediation cannot degrade inorganic contaminants, bioremediation may be used to change the valence state of inorganics and cause adsorption, immobilization onto soil particulates, precipitation, uptake, accumulation, and concentration of inorganics in micro- or macroorganisms.

PCBs and persistent organic pesticides (e.g., DDT) are relatively resistant to bioremediation techniques. A demonstration project was performed on Savannah River soils to study the effects of enhanced bioremediation on PCBs and various pesticides (e.g., DDT, DDE, DDE, and endrin) (Beul et al 2003). The results indicated that PCB concentration reductions of up to 70 percent were possible. Reductions in pesticide concentrations observed in the same study ranged from 30 to 90 percent. The range of contaminant reductions observed in the Savannah River study was used in the semi-quantitative technology evaluation. The results indicate that biological treatment will likely not be effective in treating PCB and DDT contaminated sediments to achieve site cleanup goals.

The process options under biological treatment technologies screened as part of this FS include:

- Land Treatment
- Composting
- Biopiles
- Fungal Biodegradation
- Slurry Phase Treatment
- Enhanced Biodegradation

Biological Technologies Description Summary

Land Treatment

This technology involves large-scale treatment to reduce contaminant concentrations through biological processes. This technology is generally applicable to petroleum hydrocarbons and PAHs.

Composting

This technology is similar to land treatment and reduces contaminant concentrations through composting. This technology is generally applicable to petroleum hydrocarbons and PAHs.

Biopiles

This technology is also similar to land treatment and reduces contaminant concentrations through biopiles. This technology is generally applicable to petroleum hydrocarbons and PAHs.

Fungal Biodegradation

This technology is similar to land treatment and reduces contaminant concentrations through fungal plants. This technology is generally applicable to petroleum hydrocarbons and PAHs.

Slurry Phase Treatment

This technology treats contaminants biologically in a slurry phase. This technology is generally applicable to petroleum hydrocarbons and PAHs.

Enhanced Biodegradation

This technology involves acceleration of natural biodegradation processes by providing oxygen, reducing agents, nutrients, and degrading microorganisms. This technology is not considered effective for metals, PCBs, TBT, or dioxins and is expected to be difficult to implement.

Thermal Treatment Technologies

The process options under thermal treatment technologies screened as part of this FS include incineration and thermal desorption. Incineration involves thermal incineration of contaminated sediments. Incineration destroys a range of chemicals, such as PCBs, solvents, dioxin, and pesticides by thermally decomposing the contaminants via

Commented [A80]: Could you provide a little more information about these technologies? Even one more sentence might do it.

oxidation at temperatures greater than 1,600°F. The efficiency of the process depends on three main parameters: temperature of the combustion chamber, residence time of the sediment in the combustion chamber, and turbulent mixing of the sediment. Thermal desorption is a thermal-induced physical process where contaminants and water are vaporized from a solid matrix and transported to a gas treatment system. The bed temperatures and residence times designed into these systems will volatilize selected contaminants but will typically not oxidize them. Based on the operating temperature of the desorber, thermal desorption processes can be categorized into two groups: high temperature thermal desorption, which operates at temperatures between 600 and 1,000°F, and low temperature thermal desorption, which operates at temperatures between 200 to 600°F.

The process options under thermal treatment technologies screened as part of this FS include:

- Incineration
- Pyrolysis
- Thermal Desorption
  - Low Temperature Thermal Desorption
  - High Temperature Thermal Desorption
- High Temperature Thermal Desorption
- High Pressure Oxidation
- Vitrification

Thermal Technologies Description Summary
Incineration
This process option involves thermal incineration of contaminated sediments. Incineration destroys a range of chemicals, such as PCBs, solvents, dioxins, and pesticides by thermally decomposing the contaminants via oxidation at temperatures greater than 1,600°F. The efficiency of the process depends on three main parameters: temperature of the combustion chamber, residence time of the sediment in the combustion chamber, and turbulent mixing of the sediment.

Pyrolysis
This process option consists of chemical decomposition induced in organic materials by heat in the absence of oxygen. Pyrolysis typically occurs under pressure and at operating temperatures above 430°C (800°F).

Thermal Desorption
Thermal desorption is a thermal-induced physical process where contaminants and water are vaporized from a solid matrix and transported to a gas treatment system. The bed temperatures and residence times designed into these systems will volatilize selected contaminants but will typically not oxidize them. Based on the operating

temperature of the desorber, thermal desorption processes can be categorized into two groups: high temperature thermal desorption, which operates at temperatures between 600 and 1,000°F, and low temperature thermal desorption, which operates at temperatures between 200 to 600°F.

High Pressure Oxidation
This technology uses a combination of high pressure and temperature to break down organic compounds. It consists of two different process options – wet air oxidation and supercritical water oxidation. Both processes use the combination of high temperature and pressure to break down organic compounds. Although this technology can be effective for petroleum products and PAHs, it is not considered effective for treating PCBs.

Vitrification
This process involves heating contaminated sediments through application of electrical current. Vitrification is a thermal solidification process, conducted at temperatures greater than 2,900°F to melt the sediment particles, that results in the formation of a glass aggregate. The glass aggregate can be beneficially reused as a feedstock for Portland Cement. The high temperatures destroy any organic constituents with very few by-products, and metals are incorporated into a glass structure that is resistant to leaching. The primary vitrification process options include the Minergy Glass Furnace Technology and the Gas Technology Institute Cement-Lock™ Technology. Both vendors have completed full-scale demonstrations indicating contaminant removal efficiencies greater than 99 percent for organic contaminants and between 80 and 95 percent for metals. However, to date, neither of these technologies has performed a demonstration project with a processing rate greater than 1 cubic yard/hour. ~~Therefore,~~ ~~i~~It is uncertain whether ~~or not~~ these vitrification units are able to maintain the demonstrated decontamination efficiency levels for long periods of time necessary to treat large sediment volumes.

2.4.1.8.1 Ex-Situ Treatment Evaluation Screening Criteria

General Ex-Situ Treatment Implementability Concerns
There are a number of implementability issues that are common to ex-situ treatment technologies in general including:

- For ex-situ treatment to be implementable, it must be possible to remove the sediments from their current location. Thus, ex-situ treatment is only potentially implementable where removal is effective and implementable as determined in the removal section above.

- In order for a treatment technology to be considered implementable, it should be demonstrated effective on a scale similar to the conditions being evaluated. Although this is not applied as a rigid rule in the implementability screening, technologies that are only demonstrated on scales smaller than most of the localized SMAs are considered less certain to be implementable at this Site. To date, of the three ex-situ technologies selected for further evaluation, only stabilization/solidification has been implemented on a scale with a treatment production rate greater than 1 cubic yard/hour.

- The sediment must be removed, transported (e.g., by barge), and transloaded to an upland facility where property is available for stockpiling areas and treatment equipment. Stockpiling and treatment facilities located beyond the footprint of the CERCLA Site boundary will be subject to environmental reviews and permitting requirements established by local and Oregon regulations.
- These facilities must be developed to include any necessary BMPs to minimize potential environmental impacts during treatment (e.g., spillage of contaminated sediments, minimization of rainfall/runoff from stockpiled sediment or treated sediment, odor and air emission controls, oil/hydraulic fluid spill containment, containment of untreated water and discharge of treated water, etc.). Finally, the treated material and any treatment residuals (e.g., wastewater and concentrated sludges) must be potentially stockpiled and eventually transported to their final destination(s).
- ~~In many cases,~~Often, ~~the treatment facility sizes will be~~treatment facilities need to be quite large to allow for stockpiling of enough dredged sediment so that processing could occur throughout the year when environmental dredging outside of the environmental work window is not allowed. Depending on size requirements, to find a suitably-sized site, the treatment facility may need to be located several miles away from the river.
- Pre-treatment steps (e.g., dewatering and debris removal) are necessary to prepare the sediment for efficient treatment. These steps must be included in either the transport/transload process and/or built into the treatment facility.
- For most of the technologies, treatment residuals (e.g., wastewater and emissions control systems waste) will be produced. Wastewater will be generated by dewatering steps, and this water will either require treatment prior to discharge to the lower Willamette River or disposal at a publicly owned treatment works (POTW) facility. In some cases, such as for the emissions control waste, the treatment residuals may consist of media that is more impacted than the untreated sediment.
- It may be difficult to match treated materials to specific destinations and uses as noted above. In the event that such matches cannot be identified in a timely manner, it may be necessary to establish a long-term stockpiling area that can hold several seasons of treated sediment.

Commented [A81]: Were these stated in the text already? If so, would be good to provide a reminder here.

Commented [A82]: May need to be?

In addition~~,~~ to these general implementability issues for ex-situ treatment, implementability considerations specific to each technology are discussed below separately under each category of technologies.

Physical Technologies Screening Evaluation

Stabilization/solidification with asphalt emulsions is suitable for metals but not effective for organics. Portland cement-based or bentonite-based materials may not detoxify contaminants such as PCBs and dioxins, but would be effective in solidifying the contaminated materials thus preventing contaminant migration. The most appropriate stabilization/solidification mixture would have to be determined based on bench-scale studies. The success of this method also depends on the ability to effectively mix the appropriate stabilization/solidification agent with the contaminated sediment from the site.

Due to the presence of a high amount of recalcitrant compounds such as PCBs and dioxins, high organic content, and low grain size of the sediments, particle separation and sediment washing techniques are likely to have low treatment effectiveness.

All dewatering techniques are likely to be mostly effective; different process options for dewatering could be combined during different stages of implementation to increase effectiveness.

Commented [A83]: Confusing to have this here when you do the detailed dewatering evaluation below. Move this to dewatering section or, at a minimum, reference that section.

All physical technologies would have implementation concerns primarily due to the highly organic nature and low grain size of the contaminated sediments which would present significant challenges with regards to material handling and transportation. However, they can be overcome through proper application of ancillary technologies such as dewatering. General concerns with regard~~s~~ to implementability of treatment are discussed earlier in Section 2.4.2.8. Implementability of stabilization/solidification is expected to be higher compared to other primary physical technologies since stabilization/solidification by itself improves material handling properties unlike other primary treatment technologies.

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Physical Technologies Conclusion

Based on the screening and evaluation of physical treatment technologies, stabilization/solidification with cement-based or bentonite-based agents is retained for further evaluation in this FS. Process options involving particle separation and sediment washing are eliminated from further evaluation. Stabilization/ solidification ~~with the process option~~ using asphalt emulsion is also screened out ~~from further consideration~~ due to low effectiveness.

Chemical Treatment Technologies Screening Evaluation Criteria

All the chemical technologies evaluated herein have effectiveness concerns. Technologies such as chemical oxidation/reduction are applicable only to VOCs, SVOCs, and PAHs. Although some of the process options such as solvent extraction address PCBs, generally these would not address metals and would require a treatment train using solvent extraction to be effective. Solvent extraction may have additional implementation issues due to wide ranging COCs in the contaminated materials.

In addition to general implementation concerns under ex-situ treatment, some of the process options necessitate maintenance of controlled conditions during the reactions. This presents significant implementation challenges. Handling and/or disposal of toxic treatment by-products also pose additional implementation issues. A large staging area is required for solar detoxification. Acid extraction poses additional safety concerns with regard~~s~~ to handling acids and may require pH adjustment prior to disposal.

Due to multiple effectiveness and implementation issues associated with all the chemical treatment process options, none of the technologies under this category are retained for further evaluation in this FS.

Biological Treatment Technologies Screening Criteria

Biological methods generally target organic compounds, with effectiveness for most methods limited to PAHs and petroleum hydrocarbons. Some methods are effective for VOCs and SVOCs, but biological processes are generally ineffective for PCBs, dioxins, and metals. Effectiveness of some biological processes may be severely limited due to high concentrations of contaminant compounds or certain components such as iron.

In addition to ~~general~~ implementability concerns ~~during~~ about ex-situ treatment in general, there are specific concerns related to biological process options. Most methods require large staging areas and measures to address air quality impacts ~~by~~ resulting from staging contaminated sediments in open areas. Slurry phase treatment requires constant maintenance of slurry concentrations through moisture control and treatment and disposal of process water. Enhanced biodegradation requires delivery of chemical agents or enzymes that promote biological processes. This delivery is extremely difficult to implement due to the heterogeneous nature of the contaminated sediments.

Biological Technologies Conclusion

Due to effectiveness concerns for metals and some recalcitrant organics, none of the biological technologies are retained for further evaluation in this FS.

Thermal Treatment Technologies Screening Criteria

Because high-temperature thermal desorption is a high-energy consumption method, it is typically reserved for media that possess high concentrations of highly toxic contaminants. However, unlike technologies that operate at even higher temperatures

Commented [A85]: Reference previous discussion of this.

(e.g., incineration), thermal desorption is not effective in reducing contaminant concentrations to very low levels for contaminants with boiling points close to maximum operating temperatures. For organics, the effectiveness of the low- and high-temperature units is contaminant-specific and generally controlled by the boiling point of the contaminant. All thermal methods have high overall effectiveness in addressing VOCs, SVOCs, and PAHs. Low-temperature thermal desorption and pyrolysis generally have low effectiveness ~~generally~~ in treating PCBs. For pesticides, low-temperature thermal desorption shows low effectiveness, and high pressure oxidation is somewhat effective. Thermal technologies generally do not address metals, though moderate concentration reductions occur via volatilization during incineration.

All thermal methods are highly aggressive and energy intensive, and hence, are highly difficult to implement compared to other physical, chemical and biological methods. All thermal technologies involve generation of gases, hence effective air pollution control is required, which makes implementation challenging.

Thermal Technologies Conclusion

Due to effectiveness concerns for metals and some recalcitrant organics of high boiling point, thermal technologies are generally unsuitable for treating the contaminated sediments at the Site. However, the high concentrations associated with incineration generally result in complete decomposition of PCBs and other organic chemicals. Incineration is also effective across a wide range of sediment characteristics. Although the nearest existing, permitted incineration facility is located over 500 miles from the Portland Harbor Site, incineration has been retained to address potential land disposal restrictions for highly contaminated sediments.

Dewatering Evaluation

After removal, dredged sediment may require dewatering to reduce the sediment water content. Dewatering is considered a form of ex-situ treatment because it reduces the volume and mobility of contaminants. Dewatering technologies are commonly used to reduce the amount of water in dredged sediment and to prepare the sediment for transport and treatment or disposal. In many cases, the dewatering effluent will need to be treated before it can be disposed of properly or discharged back to receiving water. Dewatering is considered in greater detail here than in the physical ex-situ treatment section because of its common application in environmental dredging projects. Several factors must be considered when selecting an appropriate dewatering treatment technology including physical characteristics of the sediment, selected dredging method, and the required moisture content of the material to allow for the next re-handling, treatment, transport, or disposal steps in the process.

Commented [A86]: This sentence is confusing. Maybe "Thermal desorption operates at lower temperatures, and thus uses less energy, than other thermal treatment technologies, but it is not as effective compared to other thermal treatment technologies…"

Commented [A87]: Is this sentence meant to clarify the previous sentence? If so, you might want to put it in parentheses.

Commented [A88]: Should add an opening sentence that explains the context of this section (e.g., a type of ex-situ physical treatment to be used in conjunction with… Discussed briefly above; more detailed discussion here. Can move the later sentence to that effect to after the intro sentence.

Three categories of dewatering that are regularly implemented include passive dewatering, mechanical dewatering, and reagent enhanced dewatering/stabilizing methods. The following sections discuss the effectiveness and implementability of various dewatering process options applicable to the Site.

Passive Dewatering

Passive dewatering (also referred to as gravity dewatering) is facilitated through natural evaporation, consolidation, and drainage of sediment porewater to reduce the dredged sediment water content. Passive dewatering is usually applied to mechanical dredging process options when space permits. Passive dewatering is most often facilitated through the use of an onshore temporary holding facility such as a dewatering lagoon or temporary settling basin. In-barge settling and subsequent decanting can also be an effective passive dewatering method and can reduce the overall time needed for onshore passive dewatering operations. Passive dewatering techniques can also be applied to sediment that has been hydraulically dredged where the resulting slurry is pumped into a consolidation site and the sediment slurry is allowed to settle, clarify, and dewater by gravity after the site has reached capacity. Water generated during the dewatering process is typically discharged to receiving waters directly after some level of treatment, or may be captured and transported to an off-site treatment and discharge location. Normal passive dewatering typically requires little or no treatability testing, although characteristics of the sediment such as grain size, plasticity, settling characteristics and NAPL content are typically considered to determine specific dewatering methods, to size the dewatering area, and to estimate the timeframe required for implementation.

Passive dewatering is generally effective and capable of handling variable process flow rates but can require significant amounts of space (depending on the volume of material processed and the settling characteristics of the sediment) and time for significant water content reduction. Passive dewatering is a widely implemented dewatering technology for mechanically dredged sediments. It is also amenable to hydraulic dredging with placement into a settling basin or with the use of geotextile tubes to confine slurry and sediment during passive dewatering. Hydraulic dredge sediment dewatering with geotextile tubes has been implemented at several sites but typically requires project-specific bench-scale evaluations during remedial design to confirm its compatibility with Site sediments and to properly select and size the geotextile tubes.

Depending on the desired moisture content of the sediment, the subsequent processing or handling steps, the volume of material to be dewatered, available space, and the ability to effectively manage the dewatering effluent, passive dewatering can be a highly implementable dewatering technology option. Passive dewatering has been retained as a process option for the Portland Harbor Site with in-barge passive dewatering selected as the representative process option for inclusion in the development of alternatives.

Mechanical Dewatering

Mechanical dewatering involves the use of equipment such as centrifuges, hydrocyclones, belt presses, or plate-and-frame filter presses to separate coarse materials, or squeeze, press, or otherwise draw out water from sediment pore spaces. Mechanical dewatering is typically used in combination with hydraulic dredging to reduce the water content of the dredge slurry prior to beneficial reuse (e.g., sands retained from particle separation methods), ex-situ treatment (e.g., thermal), and/or disposal of the dewatered sediment. Mechanical dewatering may also be used in combination with mechanical dredging if the dredged material is hydraulically re-slurried from the barge. Sufficient onshore space is needed to accommodate the selected dewatering equipment, but this space is usually less than required for passive dewatering. A mechanical dewatering treatment train usually includes treating the dewater prior to discharge.

Commented [A89]: Is this a common usage? I don't usually see this as a noun.

The mechanical dewatering treatment train typically includes screening to remove materials such as debris, rocks, and coarse gravel. If appropriate, polymers may be added for thickening prior to dewatering. These steps result in a dewatered cake that achieves project-specific volume and weight reduction goals of the dredged sediment. The mechanical dewatering process can be scaled to handle large volumes of sediment, but requires operator attention, consistent flow rates, and consistent sediment feed quality.

Mechanical dewatering is generally an effective technology for both hydraulic and mechanical dredging, ~~and~~ has been widely implemented for a range of sediment types and sediment end uses (e.g., beneficial reuse and upland disposal), and is likely the most effective method of achieving moisture content reduction over shorter timeframes than passive dewatering. Bench-scale tests are often performed during remedial design to develop the specific process design, select equipment, and to select polymer additives if appropriate. Mechanical dewatering has been retained as a process option for contaminated sediments at the Portland Harbor Site and may be used where appropriate based on SMA specific design needs.

Reagent Dewatering

Reagent dewatering is an innovative ex-situ treatment method in the category of stabilization/solidification methods, which are discussed along with other categories of ex-situ treatment. This technology does not remove water in the sense that passive and mechanical dewatering do; rather, reagent additive dewatering binds the water within the sediment matrix, increasing the mass of sediment relative to other dewatering technologies through both the added weight of the reagent and the added sediment, immobilization of leachable contaminants (typically metals contamination), and/or enhancement of geotechnical properties.

Commented [A90]: The end of this sentence is unclear. What list earlier in the sentence are these two items a part of?

For situations where dewatering is the single goal, the most cost-effective, available, and effective reagent or absorptive additive is used, which, depending on site conditions and economics, could include quicklime, Portland cement, fly ash, diatomaceous earth, or sawdust, among others. Reagent mixtures can be optimized to provide enhanced strength or leachate retardation to meet specific project requirements.

Dewatering by the addition of reagents is effective and has similar or smaller space and operational requirements as mechanical dewatering. In some cases, reagent addition and mixing can be conducted as part of the dredged material transport and rehandling process, either on the barge or as dredge material is loaded into trucks or rail cars. In other cases it can be added and mixed after offloading to the upland staging area. ~~Also r~~Reagent addition may also be used in combination with other forms of dewatering (e.g., filter press) and ex-situ treatment. Bench-scale testing is often necessary to determine the optimum reagent mixture prior to construction. However, case study information is available from other projects on the types of reagents used for sediments of various water contents, and this information is sufficient to determine the general effectiveness and implementability of this technology for this FS. For example, the Gasco Early Action used in-barge application and mixing of Portland cement as well as diatomaceous earth at the transload facility as a final dewatering “polishing” step. This approach required no extra upland treatment space or major changes to the transport and transload steps that would have otherwise been used.

Commented [A91]: Universal comment: should use the term “dredged material” and “dredged sediment”, not dredge.

Like other elements of the removal process, a wide range of dewatering process options are likely feasible at the Site. As a result, reagent dewatering has been retained as a process option for contaminated sediments at the Portland Harbor Site and may be used where appropriate based on SMA specific design needs.

Ex-situ Treatment Conclusions

Based on the screening criteria of effectiveness and implementability, ex-situ treatment using solidification/stabilization has been selected as the representative process option for further consideration during the development of remedial alternatives in the Portland Harbor FS. In addition, several ancillary process options under the dewatering technology such as in-barge dewatering, lagoon dewatering, geotextile tube dewatering, mechanical dewatering using filter presses, and dewatering using chemically absorbent reagents were also retained for further evaluation with in-barge passive dewatering selected as the representative dewatering process option.

Commented [A92]: This is confusing because I don’t recall all of these being discussed in sufficient detail to be now called out as process options to be carried forward. For instance, lagoon dewatering is only mentioned in passing.

2.5 SECTION 2 SUMMARY

This section establishes the basis for developing remedial action alternatives at the Portland Harbor Site. This section establishes RAOs and selects COCs based on the results of the BHHRA and BERA that will serve as the basis for evaluating cleanup options at the Site. This section also presents PRGs based on consideration of RBTs, ARARs, and background estimates. Finally, this section evaluates remedial technologies and process options to identify those process options that should be considered during the development of remedial action alternatives including the selection of representative process options for evaluation of remedial action alternatives.

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